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A STUDY OF OIL SPILL RATES IN FOUR U.S. COASTAL REGIONS.(U)

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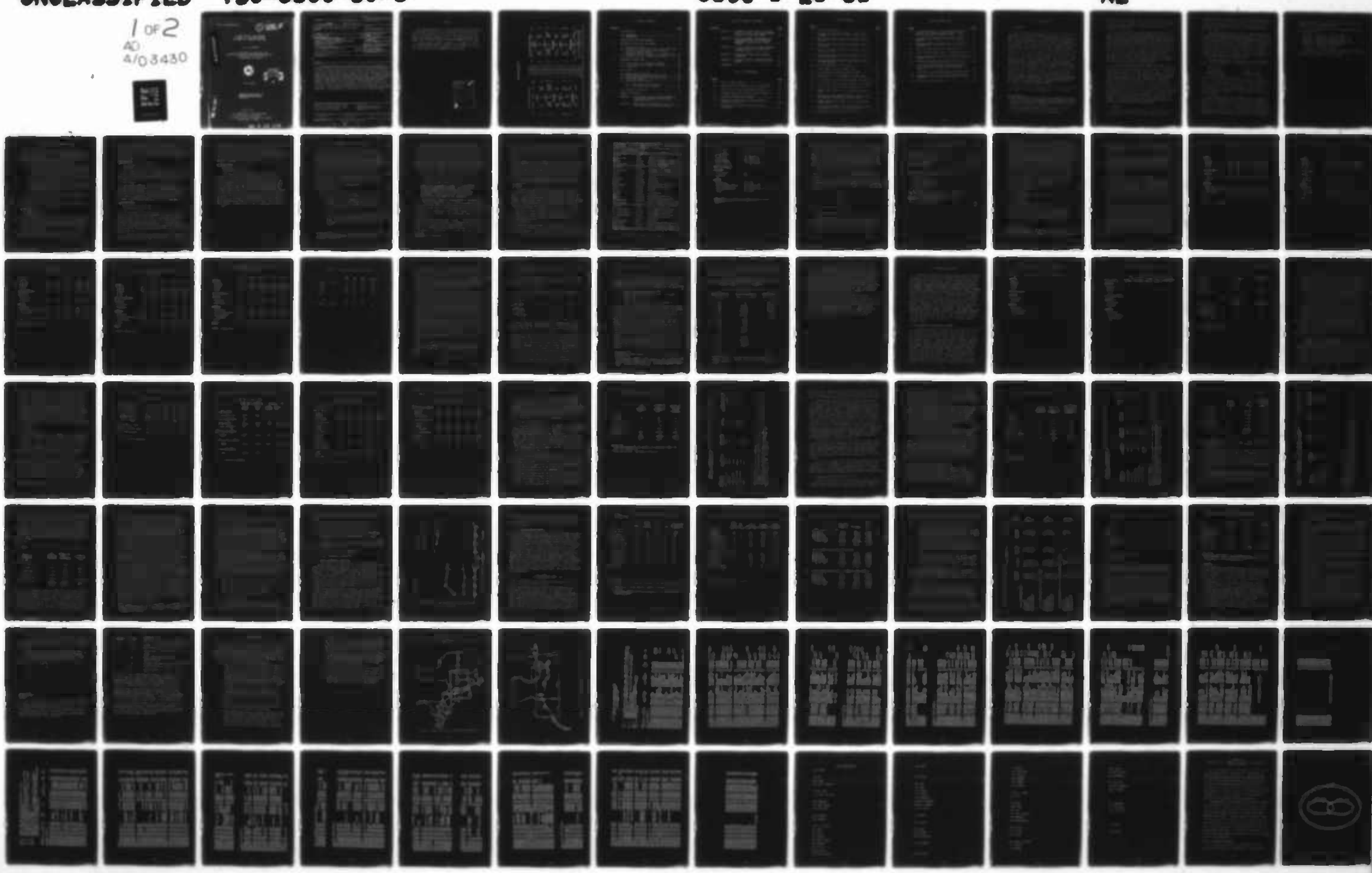

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REPORT NO. CG-D-26-81

A STUDY OF OIL SPILL RATES IN FOUR U.S. COASTAL REGIONS

J.F. BELLANTONI

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
Transportation Systems Center
Cambridge MA 02142

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
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16. Abstract

A comparison of the rates of incidence of oil spills over 10,000 gallons in the years 1974 through 1977 was made for four regions in the United States that carry heavy oil traffic: Greater New York - New Jersey, Delaware Bay, the Louisiana Coast, and the Northern Texas Coast. The spill data for the study were drawn from the Pollution Incident Reporting System (PIRS), the records of the National Response Center (NRC), and the Vessel Casualty Reporting System (VCS). Oil movement data were obtained from the Army Corps of Engineers, Waterborne Commerce of the United States. The spill rates calculated for the four regions showed no significant differences. However, a significantly higher spill rate was noted for the Hudson River subdivision of the New York - New Jersey region. An examination of the spill reports showed that most of the spills were associated with poor weather conditions (viz., ice, fog). A partial study was also made of spills in the Mississippi, Illinois, and Ohio Rivers. It was found that the spill rates in the Ohio River were significantly higher than in the Mississippi or Illinois Rivers or in the coastal regions.

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PREFACE

This memorandum reports on work undertaken by the Office of Air and Marine Systems of the Transportation Systems Center for the U.S. Coast Guard Office of Marine Environment and Systems, under Project Plan Agreement CG 915. The task covered by this report was initiated in October 1978 and completed in May 1979.

The assistance of CDR J. Valenti, Lt. M. Tobbe, Lt. CDR J. Clow, CDR W. Ecker, and of Ensigns R. Miller and M. Ives of the U.S. Coast Guard is acknowledged with appreciation.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

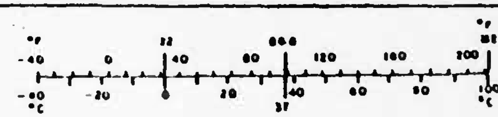

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (CONT.)

1. INTRODUCTION

1.1 BACKGROUND

The United States Coast Guard has long been involved in the protection of the marine environment against spills of oil and other injurious substances.[1] The Water Quality Improvement Act (1970) and the Federal Water Pollution Control Act Amendments of 1972, however, gave the Coast Guard extensive responsibilities in the prevention, enforcement, surveillance, response, abatement, amd impact assessment of oil spills. These responsibilities fall under the USCG Marine Environment Protection (MEP) program. The need for comprehensive oil spill statistics was soon recognized by the U.S. Coast Guard, which established the Pollution Incident Reporting System (PIRS) in December 1971. Soon after the 1972 legislation, and in compliance with it, the National Response Center (NRC) was established. The NRC includes a Central Reporting System for oil and hazardous materials.[2] The accumulation by PIRS and NRC of detailed oil spill data since 1971 opens several possibilities for quantitative management techniques. (See, for example, Reference 2). Some of the uses of these data are (a) evalution of effectiveness of proposed MEP measures,[3] (b) evaluation of effectiveness of measures previously put in force, and (c) program and budget planning.

Many analyses can be accomplished using oil spill data alone. A few methods, however, require <u>rate</u> data, i.e., spill data

---

(1) The Rivers and Harbors Act of 1899, which prohibits the dumping of refuse in U.S. navigable waters, is jointly administered by the U.S. Army Corps of Engineers, the Department of Justice and the U.S. Coast Guard. The term 'refuse' has been interpreted by the courts to include oil.

(2) The Central Reporting System is required by the Hazardous Materials Transportation Control Act of 1970.

(3) As an example of this application, see Reference 1.

normalized to some exposure measure such as petroleum movement, production, use, or storage. The major uses to which rate information has been put are spill prediction or projection, and comparative risk studies.

Spill projection methods were developed extensively in the early 1970's by Devanney and Stewart (References 3,4 and 5) in order to provide an assessment of offshore oil development risks. They derived the posterior distribution of the number of spills that would occur for an expected future exposure, given historical spills and exposure. In practice, this distribution (the negative binomial) is very close to a Poisson distribution using the historical spill rate as a parameter. Needless to mention, spill projection methods derive their usefulness from the knowledge (or estimates) of anticipated change in the underlying exposure variable. Thus, the impact on oil spills of increased oil imports may be estimated by these methods.

In comparative risk studies the emphasis is on the differences of spill rates, such as occur from one transport method to another, or from one geographic area to another. To make the comparison meaningful, the same or equivalent exposure variables must be used in both cases. This technique has been conspicuous in the tanker/pipeline controversy (Reference 6), in the U.S./foreign flag tanker question (Reference 7) and in offshore/onshore production risk comparisons. A recent study has shown (Reference 8) differences in rates of occurrence of spills over 50,000 gallons from one part of the U.S. coastal area to another. Such differences, if they exist, may provide insight into different MEP measures, shipping practices, geography, navigational aids or other characteristics that vary from one coastal area to another. It is the investigation of these regional spill rate differences that motivates the present report.

1.2 OBJECTIVE

The present study deals with spill rates in the New York, Delaware Bay, Louisiana and North Texas regions of the U.S.

coast, as employed in Reference 8. The purpose is to determine what differences, if any, exist in the spill rates for the four regions when a larger set of spills (i.e., spills over 10,000 gallons) is considered, and to analyze the possible causes of such differences.

Spill rates were obtained for the four regions in Reference 8 by dividing the number of spills in the region in 1974-77, as contained in the Major Oil Spill Information System (MOSIS) file, by an estimate of the total tonnage of waterborne oil movement in the same region and time period. The MOSIS file is a composite of spills over 50,000 gallons extracted from the U.S. Coast Guard Pollution Incident Reporting System (PIRS) and the National Response Center (NRC) files. The oil movement in the regions was estimated from Army Corps of Engineers (ACOE) data (Reference 9) on Waterborne Commerce of the United States.

The least square fits to the regional spill and throughput data, as given in Reference 8, Section 3.3.1.2, are as follows:

Greater New York:	$n = -0.171 + 0.0212\ V$
Delaware Bay:	$n = 0.0627\ V$
Louisiana Coast	$n = 0.852 + 0.0682\ V$
North Texas Coast:	$n = 0.818 + 0.0193\ V$,

where n is the number of spills and V is the oil throughput volume in millions of short tons. These estimates are affected not only by the restriction on spill size (only spills over 50,000 gallons) but also by the geographic limits taken to define the regions, and by the selection of type of spill (vessel, transfer, pipeline, onshore, etc.) and by the type of oil movement considered.

The first step taken in this report will be to refine the definitions of the four regions. The next, and most important, step will be to expand the data base of spills to encompass all spills over 10,000 gallons in the four regions in the calendar years 1974-77. Then, the oil movement data will be analyzed and various exposure data developed. From the spill data and the exposure data, the corresponding spill rates will be calculated.

Finally, the possible causal factors will be analyzed and the significance of the results ascertained.

The above steps are carried out in the remainder of this report, as follows:

Section 2: Definition of the Four Regions
Section 3: Expansion of the Spill Data Base
Section 4: Analysis of Exposure Variable Data
Section 5: Calculation of Spill Rates
Section 6: Discussion of Results.

In addition to the four regions, a calculation of spill rates was carried out for the major Western Rivers. The results are reported in Appendix G of this report.

2. DEFINITION OF THE FOUR REGIONS

The four regions were selected in Reference 8 because the large number of spills and heavy oil movement within them offered the best prospects for statistically significant results. In this section the four regions are defined more precisely. The definitions take into account three considerations:

a. The boundaries of the regions should be clear enough that any spill may be classified unambiguously as being within a region or not. Moreover, a clear-cut boundary will allow one to identify those spills that are marginally in or out of the region, thus facilitating a sensitivity analysis of the regional boundaries.

b. Regional boundaries should be chosen, as far as possible, to encompass entire waterways, as defined in the ACOE Waterborne Commerce data, which is the major source of oil movement data to be employed.

c. Boundaries should coincide with the meridians and parallels to facilitate computer sort of the PIRS data on latitude and longitude.

The four regions are illustrated in Figures A-1 and A-2 in Appendix A and are described as follows:

<u>Greater New York</u>

Latitude 40° 00' to 43° 00'

Longitude 72° 00' to 74° 40'.

The latitudes are chosen to cover both the Port of New York and the Hudson River to Troy, N.Y. The longitudes are chosen to include most of Long Island Sound on the east and the northern part of the New Jersey seacoast (Sandy Hook, Perth Amboy, south to Manasquan) on the west.

The greatest oil movement, about 130 million tons/year in this region, is in the Port of New York, which includes oil movement on the New Jersey side of the harbor as well. The

Hudson River from New York to Troy is the next largest sub-area of oil movement and spills. The third level of activity occurs along the northern shore of Long Island Sound (New Haven, New London, Bridgeport). It is of some interest to determine spill rates for these sub-areas, which are indicated by the dashed lines in Figure A-1.

Delaware Bay

Latitude 38° 30' to 40° 30'
Longitude 74° 40' to 75° 45'.

This region encompasses all of Delaware Bay and the Delaware River up to Frenchtown, NJ, (about 18 miles north of Trenton, NJ). It also encompasses the ocean approaches to Delaware Bay, from the Cape May area of New Jersey to approximately the Maryland-Delaware border.

This region comprises both the large open-water body of Delaware Bay and the confined waters of the Delaware River from Wilmington DE to Trenton NJ. It is not possible to segregate the ACOE oil movement data into these two sub-regions; Delaware Bay traffic is aggregated with that from Philadelphia (south of Allegheny Avenue) and Wilmington in the ACOE tabulations.

Louisiana Coast

Latitude 28° 00' to 30° 30'
Longitude 88° 20 to 93° 40'.

This encompasses all of the central part of the Gulf Coast, from just east of Mobile and Pascagoula, AL, almost to the Texas-Louisiana border on the west. It includes Lake Charles and the Calcasieu River and Lake, but not Port Arthur, Orange, Beaumont or the Sabine-Neches Waterways. It includes almost all of the drilling platforms offshore of Louisiana and Mississippi. To the north, it covers the Mississippi River up to and including Baton Rouge, LA.

The eastern, western, and northern boundaries of this region were selected so as to avoid cutting waterways for which data is tabulated as a whole by the ACOE. On the east, the Gulf

Intracoastal waterway is tabulated from Mobile AL to New Orleans LA. On the west, the Intracoastal Waterway from Lake Charles to Sabine is tabulated as a whole. The northern boundary, unfortunately, cuts off the northern end of the Atchafalaya River, but coincides with the New Orleans - Baton Rouge section of the Mississippi River, which carries heavy traffic and which is tabulated separately, as will be seen.

X. Texas Coast

Latitude 28° 00' to 30° 30'
Longitude 93° 30' to 96° 00'.

This region is adjacent to the Louisiana Coast Region defined above, going from approximately the Texas-Louisiana border to just south of the Matagorda ship channel, which is about 40 nautical miles southwest of Freeport, TX. The major oil movements in this region take place in the Sabine-Neches Waterway (Port Arthur, Sabine, Orange, Beaumont) and in the Galveston-Houston-Texas City area. The western boundary selected for this region presents a slight problem, for it is impossible to select a meridian to the west of Freeport TX and Houston TX which does not intersect the Galveston-Corpus Christi section of the Intracoastal Waterway. The limited amount of traffic on that waterway, however, assures that any inaccuracy introduced is minor.

3. EXPANSION OF THE SPILL DATA BASE

The purpose now is to establish a data base of spills over 10,000 gallons of oil and oil products in the four geographic regions of interest in the period 1974 through 1977. Several sources of spill data are available. The primary sources employed are the Pollution Incident Reporting System (PIRS) file and the National Response Center (NRC) files. Supporting data were also extracted from the Commercial Vessel Casualty File (CVCF). All three data sources are maintained by the U.S. Coast Guard.

Although other data sources for spills in U.S. waters in the years 1974-77 are available,* they were not systematically consulted because it was believed that the PIRS and NRC files contained the vast majority of spills of interest. The validity of that assumption will be discussed later.

3.1 SELECTION CRITERIA

In addition to the geographic and temporal limits stated, two other selection criteria were employed. They are:

(a) Spills of oil or oil products. These are to be classed as crude, heavy (including asphalt, creosote, road tar, as well as the common residual oils, #4, #5, and #6), and light (including gasoline, naphtha and diesel fuels)

(b) Spills of 10,000 gallons or more. The quantity spilled (not the amount in the water) is referred to here. The value of 10,000 gallons was expected to yield a large enough data base to provide statistically significant results.

---

*Among these sources one may mention (1) The Center for Short Lived Phenomenon, Cambridge MA, (2) Lloyd's Weekly Casualty Reports, (3) The Tanker Advisory Center, New York, NY.

No constraints were applied to the spill source in the data extraction phase. Thus spills from both tranportation-related and non-transportation-related sources were extracted initially, as were both onshore and offshore sources. The extent to which spills from various sources can be related to different measures of exposure was determined after the data extraction phase. Neither were any constraints applied to the spill cause(s) or to jurisdiction (EPA vs USCG) in the extraction phase, for the same reason. Thus the intent was to obtain initially a list of all spills within the designated limits of time, location and material, that could later be related to available exposure measures.

3.2 POLLUTION INCIDENT REPORTING SYSTEM (PIRS) DATA

The Federal Water Pollution Control Act (FWPCA) Amendment of 1972 requires (Section 311 (b) (5)) that:

> "Any person in charge of a vessel or of an onshore facility or an offshore facility shall, as soon as he has knowledge of any discharge of oil or a hazardous substance from such vessel or facility in violation of paragraph (3) of this subsection, immediately notify the appropriate agency of the United States Government of such discharge."

The discharges referred to in paragraph (3) are those of "oil or hazardous substances into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone in harmful quantities as determined by the President...." In Executive Order 11735, August 3, 1973, the Coast Guard was designated as the "appropriate agency" to be notified.

The PIRS pre-dates the above statute, having been put into operation in the U.S. Coast Guard in December 1971.* From that date it was required of Coast Guard personnel to report all spills that they observed or that they came to know about, the same requirement as was imposed in 1972 on non-Coast Guard personnel

*See page 1 of Reference 10.

by the above Amendment to the FWPCA. Also, the Coast Guard is charged with enforcement of the 1972 Amendment, for all offending discharges in U.S. navigable waters, so that the PIRS includes information on penalty action as well as the spill itself. Thus, in theory, the PIRS covers all offending spills in the United States.

A facsimile of the PIRS coding sheet for a discharge is shown in Figure 3-1 (The two other coding forms, one for response and one for penalty action, are not shown). It should be noted that the water body code refers to the type of water body (one of 7 types allowed for inland and Great Lake spills, 11 types for coastal spills). The name of the water body is not recorded in PIRS. Similarly, vessel type and identification number are given, but the vessel name is not given. Ten sizes of tankships and ten sizes of barges are allowed for, plus seven other types of vessels.

The PIRS classification of sources (Reference 10, pages 26-28) served as the basis for the spill classification used in this report. As will be seen in the next section, oil movement and vessel trip data are available (Reference 9) for tankships and barges. Hence spills involving tankers and barges were segregated. Spills involving dockside oil facilities, such as transfer spills, were also extracted separately from the spill data, since they are directly related to waterborne oil movement. The remaining spills are not directly related to oil movement and were classified as (1) those connected with offshore drilling, and (2) onshore facility spills. The complete classification list, with corresponding PIRS source code numbers from Reference 10, is given in Table 3-1.

When the PIRS data tape was examined for spills over 10,000 gallons it was found to contain many records for which the latitude and longitude, or river and mile, at which the spill occurred were not recorded. These incidents all bear dates prior to

DEPARTMENT OF TRANSPORTATION U. S. COAST GUARD CG-4590 (Rev. 12-75)	POLLUTION INCIDENT REPORTING SYSTEM (PIRS) (DISCHARGE)	INPUT TO PIRS PRE-EDIT 12210M

NOTE: 1. A - Alpha, N - Numeric (zero-fill), A/N - Alpha/Numeric
2. Columns 1 thru 16 same for both cards.

	FIELD	CARD COLUMN	DATA
RECORD ID	District	1-2 (N)	
	Sequence Number	3-7 (N)	
	Date of I	8 - 13 (N)	Yr. Month Day
	Transaction Code	14 - 16 (A)	ADD/COR/DEL
DISCHARGE	Card Number	17 (N)	1
	Time of Occurrence	21 - 23 (N)	Day of Week Hour of Day
	Location	24 - 33 (A/N)	
	State	34-35 (A)	
	Water Body	36 - 38 (N)	
	Source	39 - 41 (A/N)	
	Source Identifier	42 - 49 (N)	
	Cause	51-52 (A)	
	Operation	54-55 (N)	
	Material	56 - 59 (N)	
	Quantity	60 - 67 (A/N)	
	Affected Resources	69 - 74 (A/N)	
	Report Period Date	75 - 80 (N)	Yr. Month Day
	Card Number	17 (N)	2
	Wind Speed/Direction	21 - 25 (N)	Knots ° True
	Sea Hgt/Swell Direction	26 - 30 (N)	Feet ° True
	Current Speed/Direction	31 - 35 (N)	Knots ° True
	Notifier	39-41 (A/N)	
	Anticipated Response	42 (N)	
	OPFAC Number	44 - 53 (A/N)	
	Report Period Date	75 - 80 (N)	Yr. Month Day

PREVIOUS EDITION IS OBSOLETE

FIGURE 3-1. PIRS DATA FORM (Page 1)

TABLE 3-1. SPILL CLASSIFICATION

SPILL SOURCE	PIRS CODE NUMBER
Vessel Spills	
Tankships	010 through 019
Tank Barges	030 through 039
Other Vessels	000, 050 through 058
Marine Facility*	
Offshore	
Production	506
Pipelines	402
Onshore	
Pipelines	400, 401
Other Transportation	200 through 399
Non-Transportation	500 through 504, 507 and 508
Other	900, 999

*Spills from these sources include so-called "transfer spills".

January 1976: 95 of the 316 spills over 10,000 gallons from January 1974 through January 1976 have no latitude and longitude or river and mile. These records, however, have the state in which the spill occurred, and on that basis it was possible to narrow down to 38 the number that could have occurred in any of the regions of interest. Of these, only 3 could be classified with any assurance into a region, since they were recorded as coastal spills. The remaining 35 spills bore an inland water body type code, and could not be definitely classified as in a region.

Table 3-2 shows a breakdown of the 555 PIRS records for spills of 10,000 gallons or more, from 1974 through 1977. One hundred forty-seven, or about 26%, are recorded to have occurred in these regions; 373, or 67%, are recorded as outside any of the regions; and 35, or about 6%, are possibly within the regions of interest. Of these 35 possible regional spills, the preponderance is in Texas for some unknown reason. The exact distribution of the 35 spills by state is:

Connecticut	0
New York	0
New Jersey	2
Pennsylvania	2
Louisiana	4
Texas	27.

All 35 spills occurred in 1974 or 1975.

3.3 NATIONAL RESPONSE CENTER (NRC) CENTRAL REPORTING FACILITY DATA

The National Response Center was established at USCG Headquarters and began functioning in August 1974, in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (Title 40 CFR, Part 1510). Until Jan. 1, 1977 the NRC was one of four USCG elements to which a spill could be

TABLE 3-2. ANALYSIS OF PIRS SPILL RECORDS
JANUARY 1974 - DECEMBER 1977

Number of PIRS records, oil spills of 10,000 gallons or more	555
Latitude and Longitude specified	405
River and Mile specified	55
State only specified	95
	555
Categorized to one of four regions on basis of latitude and longitude, or river and mile	
New York Region	51
Delaware Bay Region	19
Louisiana Coast Region	45
North Texas Region	29
Probably within one of the four regions, on basis of state only and water body type	3
Possibly within one of the four regions, on basis of state only and water body type	35
Not in any of the four regions	373
	555

reported.* From January 1, 1977 on it was required that all spills be reported to the NRC, if practical. Duties of the NRC include receiving, evaluating and disseminating reports of spills, and maintenance of case files on medium coastal and major inland pollution incidents. Thus a scan of the NRC files can be expected to yield spills of 10,000 gallons or more, based on the definitions of medium and major discharges. (See Reference 17, 1510.5 (ℓ)). While reporting to the NRC did not become a requirement until January 1, 1977, it nevertheless was expected, from the nature and history of the NRC, that most spills over 10,000 gallons from August 1974 onward would be recorded in its files.

The NRC case files are not coded and must be scanned manually. This was done for all cases within the four regions from August 1974 through December 1977. The process yielded a total of 79 incidents of oil spills over 10,000 gallons. The primary data extracted for each spill were:

Latitude and Longitude, or River and Mile
Location Name and State
Water Body Name
Source Name, Type Code, and Identification Number
Material Code (as in PIRS)
Quantity Spilled
Date and Time
Cause and Factor Code (as in PIRS).

It was found that quantity discharged was not always stated in the NRC files. Often the quantity recovered was reported but no estimate given of the total quantity discharged or reaching the water. In such cases, unless the information could be extracted from the PIRS file, a nominal factor of 2.0 was

*The others were (a) the pre-designated On-Scene-Coordinator, (b) the Officer-in-Charge of any Coast Guard unit in the vicinity of the discharge, and (c) the Commander of the Coast Guard District in which the spill occurs.

applied to the quantity recovered to estimate the quantity discharged. This process was followed also when the quantity reported discharged was less than the total quantity reported recovered.

The latitude and longitude of the spill, or the river mile, when not given in the PIRS or NRC reports, were obtained from an atlas, based on the described location. Hence some are approximate. Similary, the source code, material code, and cause/factor code were assigned using the PIRS coding manual and the NRC narrative account whenever a PIRS record for the spill could not be identified.

3.4 COMBINED PIRS AND NRC DATA - UNRECORDED SPILLS

The combined PIRS and NRC spills are listed in Appendix A. This listing also includes data from the Commercial Vessel Casualty File, the uses of which will be discussed in the next section. An analysis of the PIRS and NRC data by source and year is given for each region in Tables 3-3, 3-4, 3-5, and 3-6. The analysis for all four regions combined is given in Table 3-7. In all of these tables there is shown the number of spills in the PIRS files, in the NRC files, and in both files, in the form X/Y/Z.

The most striking feature of Table 3-7 is the relatively low fraction of all reported spills that appear both in the PIRS and NRC files. The number of distinct spills appearing in the two files is X + Y - Z, or 146 + 76 - 46 = 176, as obtained from the total shown in Table 3-7. The number of spills that appear in both files, however, is only 46 , giving an "overlap" of only 26%. Since NRC did not commence operation until August 1974, however, it does not contain many spills occurring prior to that month. Hence, only the period August 1974 through December 1977 should be considered in any estimate of recording overlap. When this is done, however, the result is still only 30%, as seen in Table 3-8.

TABLE 3-3. PIRS AND NRC SPILLS OVER 10,000 GALLONS, 1974-77

— NEW YORK —

	1974	1975	1976	1977	Total
Vessels					
Tankers	1/1/1	2/2/2	1/1/1	0/0/0	4/4/4
Barges	7/1/1	2/2/2	0/1/0	3/1/1	12/5/4
Other	2/0/0	0/0/0	1/0/0	1/0/0	4/0/0
Marine Facilities	3/1/1	1/0/0	1/0/0	3/0/0	8/1/1
Offshore					
Production	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Pipelines	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Onshore					
Pipelines	1/0/0	0/1/0	1/1/0	0/0/0	2/2/0
Other Transportation	1/0/0	0/0/0	0/0/0	2/1/1	3/1/1
Non-Transport	3/1/1	2/0/0	6/2/1	3/2/1	14/5/3
Other and Unknown	3/0/0	1/0/0	1/2/0	1/1/0	6/3/0
Total	21/4/4	8/5/4	11/7/2	13/5/3	53/21/13

LEGEND: PIRS/NRC/BOTH.

TABLE 5-4. PIRS AND NRC SPILLS OVER 10,000 GALLONS, 1974-77

— DELAWARE BAY —

	1974	1975	1976	1977	Total
Vessels					
Tankers	2/1/1	1/1/1	2/2/2	0/0/0	5/4/4
Barges	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Other	0/0/0	1/0/0	0/0/0	0/0/0	1/0/0
Marine Facilities	0/0/0	0/0/0	2/0/0	0/0/0	2/0/0
Offshore					
Production	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Pipelines	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Onshore					
Pipelines	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Other Transportation	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Non-Transport	2/0/0	3/2/0	2/1/0	1/0/0	8/3/0
Other	0/0/0	0/0/0	0/0/0	1/0/0	1/0/0
Total	4/1/1	5/3/1	6/3/2	2/0/0	17/7/4

LEGEND: PIRS/NRC/BOTH.

TABLE 3-5. PIRS AND NRC SPILLS OVER 10,000 GALLONS, 1974-77

— LOUISIANA COAST —

	1974	1975	1976	1977	Total
Vessels					
Tankers	1/1/1	2/2/2	0/1/0	0/1/0	3/5/3
Barges	3/3/1	2/3/2	3/3/3	5/3/1	13/12/7
Other	1/0/0	0/0/0	2/0/0	1/0/0	4/0/0
Marine Facilities	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Offshore					
Production	1/1/0	1/1/1	6/2/2	0/0/0	8/4/3
Pipelines	0/1/0	1/0/0	1/1/1	1/1/1	3/3/2
Onshore					
Pipelines	2/0/0	2/1/1	1/1/0	1/1/0	6/3/1
Other Transportation	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Non-Transport	1/0/0	3/2/0	1/2/1	2/1/0	7/5/1
Other	1/1/1	0/1/0	0/0/0	2/0/0	3/2/1
Total	10/7/3	11/10/6	14/10/7	12/7/2	47/34/18

LEGEND: PIRS/NRC/BOTH.

TABLE 3-6. PIRS AND NRC SPILLS OVER 10,000 GALLONS, 1974-77

— NORTH TEXAS COAST —

	1974	1975	1976	1977	Total
Vessels					
Tankers	1/0/0	1/1/1	1/1/1	1/1/1	4/3/3
Barges	3/1/1	1/1/1	2/2/2	1/1/1	6/4/4
Other	0/0/0	0/0/0	1/0/0	1/0/0	2/0/0
Marine Facilities	0/0/0	0/0/0	0/1/0	1/1/1	1/2/1
Offshore					
Production	1/0/0	0/0/0	1/0/0	0/0/0	8/3/1
Pipelines	0/0/0	1/1/1	0/0/0	0/0/0	1/1/1
Onshore					
Pipelines	6/2/1	0/1/0	0/0/0	1/0/0	7/3/1
Other Transportation	0/0/0	0/0/0	0/0/0	0/0/0	0/0/0
Non-Transport	1/1/1	2/0/0	1/0/0	1/0/0	5/1/1
Other	0/0/0	1/0/0	0/0/0	0/0/0	1/0/0
Total	12/4/3	6/4/3	5/3/2	6/3/3	29/14/11

LEGEND: PIRS/NRC/BOTH.

TABLE 3-7. PIRS AND NRC SPILLS OVER 10,000 GALLONS, 1974-77

— ALL FOUR REGIONS —

	1974	1975	1976	1977	Total
Vessels					
Tankers	5/3/3	6/6/6	4/5/4	1/2/1	16/16/14
Barges	13/5/3	5/6/5	5/6/5	9/5/3	31/21/15
Other	3/0/0	1/0/0	4/0/0	3/0/0	11/0/0
Marine Facilities	3/1/1	1/0/0	3/1/0	4/1/1	11/3/2
Offshore					
Production	2/1/0	1/1/1	6/2/2	0/0/0	9/4/3
Pipelines	0/1/0	2/1/1	1/1/1	1/1/1	4/4/3
Onshore					
Pipelines	9/2/1	2/3/1	2/2/0	2/1/0	16/8/2
Other Transportation	1/0/0	0/0/0	0/0/0	2/1/1	3/1/1
Non-Transport Facility	7/2/2	10/4/0	10/5/2	7/3/1	34/14/5
Other	4/1/1	2/1/0	1/2/0	4/1/0	11/5/1
Total	47/16/11	30/22/14	36/24/14	33/15/8	146/76/46

LEGEND: PIRS/NRC/BOTH.

TABLE 3-8. SPILLS RECORDED BY PIRS AND NRC

	By PIRS	By NRC	By Both	% Overlap
Aug. 74 - Dec. 74	15	12	8	42%
1975	30	22	14	37%
1976	36	24	14	30%
1977	33	15	8	20%
Net	X=	Y=	Z=	
Aug. 74 - Dec. 77	114	73	44	30%

Since only 50% of the reported spills appear in both files, one is led to inquire: How many spills occurred, but appeared in neither file? Surprisingly, it is possible to estimate how many spills were not recorded at all. In fact, the method for making such an estimate has long been used in estimating game population (Reference 18, p. 45) and demographic characteristics. It has also been employed by the Federal Aviation Administration (Reference 19) to estimate the actual number of near mid-air collisions (NMAC's) from two sets of pilot reports.

To apply this technique, it is necessary to assume that the spills listed in the PIRS or NRC records are selected at random from all spills over 10,000 gallons that occurred between August 1974 and December 1977. This assumption would not hold if certain types of spills were recorded by one source more consistently than other types. If, for example, vessel-related spills were not recorded by NRC with the same reliability as pipeline spills, then the estimation method would not be valid. It was not possible to ascertain, from interviews with the relevant USCG personnel, whether such a bias did indeed exist. Neither does examination of the data of Table 3-7 show any intelligible pattern. One might expect that the PIRS records, which are entered by the USCG personnel at the District level, would contain relatively more records of vessel, offshore and other marine spills than the NRC records, which are reported by all observers in the country. This, however, is not reflected in the data of Table 3-7, which show that vessel, offshore and other marine spills constitute 48% of the PIRS records and 52% of the NRC records.

Given the above assumption, however, one may estimate from Table 3-8 (see Appendix B) that the number N of spills that have actually occurred from Aug. 1974 to December 1977 in the four regions is:

$$N = X \cdot Y/Z$$
$$= 114 \cdot 73/44$$
$$= 189$$

The number of distinct spills recorded by the two sources, 144, is therefore about 75% of the number estimates to have actually occurred.

One may justifiably inquire as to the confidence that may be placed in the estimate of N. As discussed in Appendix B, the overlap I is approximately normally distributed about XY/N with variance V:

$$V = X\ (N-X)\ Y\ (N-Y)/N^3.$$

As different values of N are assumed, the distribution of the overlap I varies, according to the following table:

Assumed Value of N	=	150	165	190	235	250
Expected Overlap I	=	55.5	50.9	44.0	35.4	33.3
Variance V of Overlap	=	5.1	8.7	10.7	12.6	12.8
Probability of I $\leq$ 44	=	<.0001	.02	.50		
$\geq$ 44				.50	.02	.002

From the last line of the above table it appears unlikely that N is less than 165 or more than 235. It should be reiterated that this N applies only to the period August 1974 through December 1977.

One also may inquire as to the effect of the assumption of independent reporting. While no formal mechanism exists for PIRS or NRC to obtain data from the other system, it is possible that informal communication existed between them during the time frame of interest. If this was so, however, the estimated total number of spills would be greater than 189, rather than less, for the data. This, also, is demonstrated in Appendix B.

In summary, one must conclude that at least 13%, and most likely 25% of all oil spills over 10,000 gallons in 1974-77 went unrecorded in either PIRS or NRC, in the four regions studied. If one considers only vessel and other marine spills, however,

the most likely estimate of unrecorded spills is 15% rather than 25%.

3.5 COMMERCIAL VESSEL CASUALTY FILE (CVCF)*

The Commercial Vessel Casualty File is based on U.S. Coast Guard reports made on Forms CG-2692, CG-924E, and related reports. It encompasses all casualties to U.S. vessels, or to foreign vessels in U.S. waters, provided the casualty involved one or more of the following:

a. Property damage in excess of $1500
b. Damage affecting the seaworthiness of the vessel
c. Stranding or grounding
d. Loss of life
e. Injury producing at least 72 hours incapacity.

Oil leakage or spillage alone does not require the filing of a casualty report, unless the value of the oil or its damage exceeds $1500. Moreover, the amount of oil spilled is not included in CG-2692 and is recorded in the computerized file only as: 0 = no significant data, 1 = light oil pollution, 2 = moderate oil pollution, 3 = heavy oil pollution. The narrative reports and Form CG-2692 give more specific data than the computerized file. It was found that the computer file was adequate only for a coarse screening, because it records the date only to the month, and location only to the nearest Maritime Position number,** and the quantity of oil only approximately, as 0,1,2, or 3. Therefore it was necessary, in many cases, to examine the actual casualty file to determine whether an incident listed in the CVCF printout was distinct from a similar incident recorded in PIRS or NRC, and if so, how much oil was spilled. Even when this was done there remained some 23 cases

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* Referred to as the Merchant Vessel Casualty File (MVCF) in Reference 15.

**These "Bowditch numbers" are a set of 5-digit numbers assigned to recognizable coastal points, usually from 2 to 20 miles apart. See H.O. Publication No. 9, American Practical Navigator, N. Bowditch, any recent edition.

in the four regions, for which the CVCF was the only information source (i.e., no PIRS or NRC data) and with only the 0,1,2,3 indicator of the amount of oil spilled. This indicator, therefore, was examined in some detail.

Comparison of the CVCF pollution indicator (0,1,2,3) with quantity spilled as recorded in PIRS and in the CVCF Investigating Officer's Report yielded the following breakdown:

CVCF INDICATOR = 1 (light pollution)	CVCF INDICATOR = 2 (moderate pollution)	CVCF INDICATOR = 3 (heavy pollution)
20,000 P	11,000 P	103,000 P
13,000 P	82,000 P	32,000 P
100 V	21,000 P	102,000 P
000 V	90,000 P	63,000 P
000 V	277,000 P	210,000 P
200 V	420,000 P	378,000 P
200 V	3,000 V	900 V
1,500 V	1,474 V	
126 V	500 V	
13 V	1,000 V	
84 V	84,000 P	
2 V	103,000 P	
0 V		
160,000 P	23,000 P	
200 V	840,000 P	
60 V	84,000 P	
0 V	16,800 P	
0 V		
420 V		

P = amount spilled, in gallons, recorded in PIRS file
V = amount spilled, in gallons, shown in CVCF Investigating Officer's Report.

From this breakdown it appears that the amount recorded in the VCF Investigating Officer's Report is usually less than the amounts recorded in PIRS, for spills bearing the pollution indicator 1 or 2. Further, the VCF pollution indicator is not always consistent with itself. A spill described in the VCF case report #72373 as being approximately 1500 gallons bears an indicator of 1, (light pollution) while one described as approximately 900 gallons in case #51795 bears an indicator of 3, (heavy pollution). It should also be noted that many VCF reports did not attempt to estimate amount of pollution, referring the reader to the report of the OCMI or COTP cognizant of the spill.

Given the above uncertainties in quantity spilled, as indicated by the CVCF, the following compromise with accuracy was made: Spills for which the CVCF pollution indicator was the only information on quantity spilled were considered to be 10,000 gallons or more if the indicator was 2 or 3. This procedure, plus the Investigating Officer's estimates, yielded a total of 9 spills over and above the 144 recorded in PIRS or NRC for 1974-77: two in the New York region, one in Delaware Bay, five in Louisiana and one in North Texas.

4. EXPOSURE VARIABLE DATA

The numbers of spills in the four regions cannot be compared meaningfully unless they are normalized to some measure of spill threat exposure in each region. A useful exposure variable must be related to the type of spill that it is intended to explain. For example, transfer spills might be related to the amount of oil loaded or unloaded; collisions and groundings might be related to the total vessel miles in a waterway or harbor; onshore spills might be related to the total oil entering and leaving a region. For each of the classes of spills shown in Table 3-1, candidate exposure variables were selected from the oil and vessel movement data available in the ACOE "Waterborne Commerce of the United States." (Reference 9) This publication is the most comprehensive data source available on U.S. oil movement. The selections possible are shown in Tables 4-1 and 4-2. A check mark indicates that the spill source on the left is possibly related to the oil or vessel movement type shown at the top. Table 4-1 shows possible oil movement types and Table 4-2 shows possible vessel movement types.

4.1 OIL MOVEMENT AS AN EXPOSURE VARIABLE

It is seen in Table 4-1 that tanker spills might be related to all types of oil movement except local, and barge spills to all types of movement except foreign. When the various types of oil movement are broken down by vessel type, however, one finds the data of Table 4-3. The tonnage movement breakdown suggests that one may attempt to relate tanker spills to foreign and coastal movement, and to relate barge spills to internal and local movement. Alternately, one may attempt to relate all vessel spills to the total oil movement. The vessel trip breakdown, however, shows that most trips are made by tank barges, particularly in the Gulf coast ports. These possibilities will be explored further in the next section. It suffices to note at this point that it may be useful to segregate the oil movement

TABLE 4-1. SPILL SOURCES AND OIL MOVEMENT TYPES

Spill Source	Oil Movement Type: Foreign	Coastal	Internal	Local
Vessels				
Tankers	✓	✓	✓	
Barges		✓	✓	✓
Other				
Marine Facilities	✓	✓	✓	✓
Offshore				
Production				
Pipeline				
Onshore				
Pipelines	✓	✓	✓	✓
Other Transport	✓	✓	✓	✓
Non-Transport	✓	✓	✓	✓
Other	✓	✓	✓	✓

TABLE 4-2. SPILL SOURCES AND VESSEL MOVEMENT TYPES

	VESSEL TRIPS BY				
	Self-Propelled			Non-Self Propelled	
Spill Source	Tankers	Dry Cargo	Others	Tankers	Dry Cargo
Vessels					
Tankers	✓				
Barges				✓	
Other		✓	✓		
Marine Facilities	✓			✓	
Offshore					
Production					
Pipeline					
Onshore					
Pipelines					
Other Transport					
Non-Transport					
Other					

TABLE 4-3. ANALYSIS OF U.S. OIL MOVEMENT BY VESSEL TYPE

PERCENT BY TONNAGE MOVEMENT[1]

	Tankers	Tank Barges
Foreign	100	0
Coastal	89	11
Internal	2	98
Local	14	86

PERCENT BY VESSEL TRIPS[2]

	Tankers	Tank Barges
Atlantic Ports	39	61
Pacific Ports	27	73
Gulf Ports	10	90
Combined Ports	24	76

(1) Reference 20, Tables I-A and II-A.

(2) Reference 20, Appendix E.

data into two groups: foreign and coastal in one group and internal and local in the other.

Spills from onshore activity cannot be directly related to any one type of oil movement. Onshore pipeline spills, in particular, may not involve oil that appears in waterborne oil movement data at all. Onshore storage tank leaks, a common source of onshore spills, may involve only oil that has had land transport in its history, and that would involve only land transport in its future. Clearly, distinguishing such onshore spills from those of waterborne oil is not practical, since it requires investigation of the transport history of the spilled oil. The only practical possibility appears to be to relate all onshore spills in the region to the total waterborne movement in the region.

Transfer spills and other marine spills are logically related to the total amount of oil that is loaded or unloaded on vessels in the region of interest. This is measured by the total of foreign, coastal, internal and local tonnages excluding the "through" component of such movements. The "through" movement in a waterway is the tonnage that enters and leaves the waterway without being loaded or unloaded within the waterway. Fortunately, ACOE data list through tonnages separately within the foreign, coastal, and internal categories. (Local movements do not encompass any through traffic). Subtracting the through tonnages from the total movement should yield an exposure variable that may be related to transfer spills.

4.2 VESSEL TRIPS AS AN EXPOSURE VARIABLE

As noted above, the ACOE oil tonnage data do not distinguish barge from tanker movements for each of the four regions of interest.* However, the data do show tanker and tank barge trips by port or waterway, but not for separate commodities. If one assumes that all tankers carry oil, then the trip data may be used as a measure of tanker and tank barge activity by port or waterway. However, not all tankers carry oil, and an estimate is

*Part 5 of the ACOE volumes does give barge tonnages by commodity for the country as a whole.

needed of what fraction do so, and how that fraction varies from region to region. A check of the PIRS liquid spills over 10,000 gallons involving tankers or tank barges from 1973 through 1977, shows that 5% of tanker spills and 18% of tank barge spills were liquids other than petroleum or its derivatives.* (These percentages are unchanged when spills on the Mississippi-Ohio-Illinois River systems are excluded from the count). Hence it appears that 95% of tankship trips are connected with petroleum movement, while about 80% of tank barge trips are so connected. It is not possible to determine, from published data, how this percentage varies from region to region. It is apparent then that vessel trips can reasonably serve as an exposure variable for tanker spills but some unknown loss in accuracy occurs when applied to barge movements.

4.3 TABULATIONS

Appendix C gives oil movement tonnages for the four regions of interest, extracted from the ACOE volumes. Within each region the data are broken down by year, by type of oil (heavy, light, crude), and by waterway. Through movements are noted separately.

Appendix D gives vessel trips for the four regions of interest, also extracted from the ACOE volumes. Within each region, the data are broken down by year, by type of vessel (tanker, barge, all vessel types), and by waterway.

The totals for the four regions are given in Tables 4-4, 4-5, and 4-6. The striking feature of Tables 4-4 and 4-6 is the strong rise in tonnage in the Louisiana and North Texas regions from 1974-77. Total tonnage increased by about 57% in these four years. Tanker trips, however, increased by only 56% and barge trips were virtually unchanged. Most of the tonnage increase can be traced to crude oil imports into Baton Rouge, Lake Charles, Port Arthur, Houston/Texas City, and Freeport. (See Appendix C)

*The percentage for tank barges excludes intentional dumping of chemicals under permit.

TABLE 4-4. OIL MOVEMENT FOR FOUR COASTAL REGIONS, BY YEAR[1]

(MILLIONS OF SHORT TONS)

NEW YORK REGION	1974	1975	1976	1977	Total
Port of New York	138.8	129.4	137.5	145.9	551.7
Long Island Sound	26.6	26.3	28.0	24.7	105.7
Hudson River	18.6	17.7	18.0	17.6	71.9
Total NY Region	184.0	173.4	183.5	188.2	729.3
DELAWARE BAY, Total	105.5	96.8	106.1	105.0	413.4
LOUISIANA COAST, Total	195.8	222.9	263.2	330.1	1012.0
NORTH TEXAS, Total	161.8	156.7	189.4	228.7	736.6

(1) Extracted from Appendix C.

TABLE 4-5. OIL MOVEMENT FOR FOUR COASTAL REGIONS, BY CARRIAGE[1]

(MILLIONS OF SHORT TONS)

	Receipts & Shipments		Through		Total
	Ocean-going	Inter-nal	Ocean -going	Inter -nal	
NEW YORK REGION					
Port of New York	366.0	185.7	0.0	0.0	551.7
Long Island Sound	100.8	4.9	0.0	0.0	105.7
Hudson River	19.4	49.7	0.1	2.6	71.9
Total, NY Region	486.2	240.3	0.1	2.6	729.3
DELAWARE BAY REGION					
Total	287.9	95.4	26.8	3.4	413.4
LOUISIANA COAST REGION					
Total	272.0	276.6	198.0	265.4	1012.0
NORTH TEXAS REGION					
Total	404.6	171.6	28.6	160.4	736.6

(1) Extracted from Appendix C.

TABLE 4-6. VESSEL TRIPS FOR FOUR COASTAL REGIONS, 1974-77[1]

(THOUSANDS OF VESSEL TRIPS)

	1974	1975	1976	1977	Total
NEW YORK REGION					
Port of New York					
Tankers	74.2	63.8	60.0	51.8	249.8
Barges	93.6	85.7	84.3	78.5	342.1
All Vessels	793.5	675.9	616.0	518.2	2603.6
Long Island Sound					
Tankers	5.1	4.4	4.2	3.7	17.4
Barges	7.7	7.8	6.5	6.0	28.0
All Vessels	127.4	115.3	114.2	105.4	462.3
Hudson River					
Tankers	2.3	1.9	1.8	1.5	7.5
Barges	8.5	7.4	7.7	7.1	30.7
All Vessels	110.9	93.0	78.9	62.3	345.1
Total, NY Region					
Tankers	81.6	70.1	66.0	57.0	274.7
Barges	109.8	100.8	98.5	91.6	400.7
All Vessels	1031.7	884.1	809.2	685.9	3410.9

(1) Extracted from Appendix D.

TABLE 4-6. VESSEL TRIPS FOR FOUR COASTAL REGIONS, 1974-77 (CONTINUED)

(THOUSANDS OF VESSEL TRIPS)

	1974	1975	1976	1977	Total
DELAWARE BAY REGION					
Tankers	5.1	4.5	4.5	4.1	18.2
Barges	16.5	13.5	14.3	12.5	56.8
All Vessels	118.8	119.6	94.9	87.2	420.5
LOUISIANA COAST REGION					
Tankers	7.5	8.4	8.9	9.7	34.5
Barges	171.5	182.6	177.4	183.1	714.6
All Vessels	565.0	799.9	838.8	896.6	3100.3
NORTH TEXAS REGION					
Tankers	8.3	7.9	8.8	8.9	33.9
Barges	110.5	102.3	109.2	106.5	428.5
All Vessels	275.7	258.6	291.6	292.1	1118.1

5. SPILL RATES

The spill data and exposure data developed in the preceding sections will be combined here to yield spill rate estimates for the four regions. First, a set of estimates will be developed using tonnage of oil movement as the exposure variable, and then a set will be developed using vessel trips as the exposure variable. In both cases the spill rate estimates will be for spills of oil and oil products of 10,000 gallons or more in the four regions and in 1974-1977, derived by the method selected in Appendix E.

5.1 SPILLS PER MILLION TONS

The gross spill rates for the four regions, counting all spill sources and oil movements, are shown in Table 5-1. It appears that all regions have spill rates in the range of .04 to .07 spills per million tons except the Hudson River subsection of the New York region. The statistical significance of the observed spill rate in the Hudson River area can be tested by the method described in Appendix F. The normal approximation described there indicates that the odds against the Hudson River having the same spill rate as the remainder of the four regions are about 10,000,000,000 to 1, based on the data of Table 5-1.

It is clear then, that either the spill rate in the Hudson River is significantly different from that in the remainder of the regions, or that the Hudson River data (either spills or oil movement) are in error. This question will be treated in Section 5.5. First, it is appropriate to exclude the Hudson River data and to inquire whether any of the other regions or subregions show significant deviations from the remainder.

Table 5-2 summarizes the results of significance testing on the data for the four regions, excluding the Hudson River. The normal approximation and test procedure outlined in Appendix F were used once again. It is clear from the last column of Table 5-2 that none of the separate observations is very unlikely, given

TABLE 5-1. OVERALL SPILL RATES, 1974-77
(SPILLS PER MILLION TONS)

	All Oil Spills(1) 1974-77	Waterborne Oil Movement(2) 1974-77	Spills per Million Tons Movement
NEW YORK			
Port of NY	38	551.7	.069
LI Sound	6	105.7	.057
Hudson River	19	71.9	.264
DELAWARE BAY	22	413.4	.053
LOUISIANA COAST	68	1012.0	.067
NORTH TEXAS	34	736.6	.046
	187	2891.3	.065

(1) Includes spills from all sources, as recorded in NRC, PIRS or VCF. See Appendix A.

(2) Millions of tons. See Table 4-4 or 4-5.

TABLE 5-2. SIGNIFICANCE TEST RESULTS[(1)] FOR ALL SPILLS IN THE FOUR REGIONS, EXCLUDING THE HUDSON RIVER

Region or Subregion	Oil Movement[(4)]	Expected Spills[(2)]	Expected Variance	Probability of Observed Spills[(3)]
Port of NY	551.7	32.9	26.3	0.30
LI Sound	105.7	6.3	6.0	0.91
Delaware Bay	413.4	24.6	20.9	0.44
Louisiana Coast	1012.0	60.3	38.4	0.20
N. Texas Coast	736.6	43.9	32.2	0.08
Total	2819.4	168.00	--	--

(1) Based on tests described in Appendix F.

(2) Assumes a total of 168 spills for 1974-77 in all regions, and the oil movement of column 1.

(3) Probability of all observations that deviate from the expected number of spills by as much as or more than does the actual observation, Table 5-1.

(4) Millions of tons, in the years 1974-77.

the total of 167 spills and the hypothesis that all regional spill rates are equal. The only possible exception is North Texas, which shows a .08 probability for the actually observed number of spills.

In assessing the significance of the North Texas spill rate, it should be recalled that an inordinate number of spills of unknown location (i.e., no latitude and longitude or river and mile) were located in Texas in 1974-77. As pointed out in Section 3.2, there were a total of 27 spills of 10,000 gallons or more in the PIRS file for which the location is given only as in the state of Texas. Although all 27 spills are classified by PIRS as inland, it is possible that a large fraction of them occurred in the North Texas region as defined in this report, i.e., below 30°30' latitude and east at 96°00'. The preponderance of Texas refineries are located in this area. If only one third fell into that region, for example, then the observed number of spills would be 43 instead of 34, and the probability would be .97 instead of 0.08. In fact it is necessary for only 6 of the 27 to fall within the region to make the probability of observation reach .50.

In contrast to the situation in the North Texas region, the other three regions have relatively few possible additions to their spill totals from the list of PIRS spills with only a state location. Louisiana shows 4 such spills, and Pennsylvania and New Jersey only 2 each. These spills cannot significantly alter the observed spill numbers in the Louisiana, Delaware Bay, or New York regions.

It is to be concluded, then, that no great significance can be attached to the .08 probability calculated for the observed North Texas spills. The outcome of significance testing on the gross spill rates for the four regions, then, is that only the Hudson River subregion shows a significant variation from the other regions.

5.2 VESSEL-RELATED SPILLS PER MILLION TONS

Since total waterborne oil movement should influence vessel-related spills more directly than all spills within a region, the regional vessel-related spill rates were calculated. These are

shown in Table 5-3. The first column shows spills from tankers, barges, and marine facilities such as loading and unloading areas. Offshore production and pipelines as well as all onshore spills are excluded (see Table 3-1). The second column shows total waterborne oil movement in millions of tons, as given in Table 5-1. The third column shows spills per million tons.

It is apparent once again that the Hudson River spill rate far exceeds those in the remainder of the region. The high overall spill rate, .264 spills/million tons, exhibited for the Hudson River in Table 5-1 is almost equalled by the vessel-related spill rate, .193 spills/million tons, for the Hudson River shown in Table 5-3. Therefore, pending its subsequent examination, the Hudson River will be excluded from the vessel-related spill data and the rates examined for the remainder.

Table 5-4 shows the results of significance tests on the vessel-related spill rates of all four regions, excluding the Hudson River. It is in the same format as Table 5-2, for all spill rates.

It is seen in Table 5-4, that in all regions, other than the Hudson River, the observed number of spills is not a rare event on the hypothesis that all regions have the same spill rate. Even the addition of say, 25% of the 27 non-specifically located spills in the state of Texas, to the North Texas Coast observation, would actually increase the probability of the observation from 0.38 to over 0.90. Hence it is not possible to reject the hypothesis of a single spill rate for vessel-related spills any more than for all spills, when the Hudson River is excluded.

5.3 VESSEL-RELATED SPILLS PER VESSEL TRIP

A third possibility that should be explored is that of a difference of spill rates employing vessel trips as the exposure variable. The most promising exposure variable is obviously trips by tankers and barges, since a very large fraction of them carry oil exclusively. These trips may be construed as the variable underlying the vessel-related oil spills. Table 5-5 shows the

TABLE 5-3. VESSEL-RELATED SPILL RATES, 1974-77
(SPILLS PER MILLION TONS)

	Vessel-Related Spills(1)	Waterborne Oil Movement(2)	Vessel-Related Spills per Million Tons Movement
NEW YORK			
Port of NY	14	551.7	.025
LI Sound	3	105.7	.028
Hudson River	14	71.9	.195
DELAWARE BAY	9	413.4	.022
LOUISIANA COAST	32	1012.0	.032
NORTH TEXAS	16	736.6	.022
	88	2891.3	.030

(1) See Appendix A.
(2) Millions of short tons.

TABLE 5-4. SIGNIFICANCE TESTS[1] FOR VESSEL-RELATED SPILLS IN FOUR REGIONS, EXCLUDING THE HUDSON RIVER

Region or Subregion	Oil Movement[4]	Expected Spills[2]	Expected Variance	Probability of Observed Spills[3]
Port of NY	551.7	14.5	11.6	0.88
LI Sound	105.7	2.8	2.7	0.90
Delaware Bay	413.4	10.8	9.3	0.66
Louisiana Coast	1012.0	26.6	17.0	0.20
N. Texas Coast	736.6	19.3	14.3	0.38
	2819.4	74.00		

(1) Based on Appendix F.

(2) Assumes a total of 72 spills for 1974-77 in all regions, and the oil movement of column 1.

(3) Probability fo all observations that deviate from the expected number of spills by as much as or more than does the actual observation, Table 5-3.

(4) Millions of tons, in the years 1974-77, as given in Appendix C.

TABLE 5-5. VESSEL-RELATED SPILLS PER TRIP, 1974-77

	Vessel-Related Spills	Tanker and Barge Trips	Vessel-Related Spills per Thousand Trips
NEW YORK			
Port of NY	14	591,825	0.0236
LI Sound	3	45,333	0.0661
Hudson River	14	38,369	0.3649
DELAWARE BAY	9	75,035	0.1200
LOUISIANA COAST	32	749,142	0.0427
NORTH TEXAS	16	462,393	0.0346
	88	1,962,117	0.0448

rates for the four regions. The barge and tanker trip data are taken from Appendix D, while the vessel-related spills are the same as in Table 5-3.

Once again the spill rate for the Hudson River stands out well above all other regions or sub-regions. A significance test using the method of Appendix F shows the probability of observing 14 spills in the Hudson River, given a total of 86 spills and the indicated tanker and barge trips, is less than 1 in 10^{10}. Therefore the Hudson River data will be reserved for later examination, and tests performed on the remaining data. The results are shown in Table 5-6.

From Table 5-6, it is seen that Delaware Bay shows a significantly higher number of vessel-related spills per tanker and barge trip than do the other regions. The data show a total of 9 such spills, while only 2.9 are expected on the basis of the region's vessel trips.

TABLE 5-6. SIGNIFICANCE TESTS[1] FOR VESSEL-RELATED SPILLS PER THOUSAND TANKER AND BARGE TRIPS, IN FOUR REGIONS, EXCLUDING THE HUDSON RIVER

Region or Subregion	Tanker and Barge Trips[2]	Expected Spills[3]	Expected Variance	Probability of Observed Spills[4]
Port of NY	591.8	22.8	15.8	.03
LI Sound	45.4	1.7	1.7	.32
Delaware Bay	75.0	2.9	2.8	.0004
Louisiana Coast	749.1	28.8	17.6	.45
N. Texas Coast	462.4	17.8	13.5	.62
	1923.7	74.00		

(1) Employing method of Appendix F.

(2) Thousands of trips, 1974-77, as given in Appendix D.

(3) Assumes a total of 72 spills, and vessel trips of preceding column.

(4) Probability of all observations that deviate from the expected number of spills by as much as or more than does the actual observation, Table 5-5.

Since Delaware Bay does not show a high spill rate when total oil tonnage is employed as the exposure variable, one is led to explore the total tonnage per barge or tanker trip for the four regions. This comparison is made in Table 5-7. The figures vary from a low of 932 tons per trip for the Port of New York subregion, to a high of 5512 tons per trip for Delaware Bay. (It will be noticed that the ratio for the Hudson River subregion is not substantially different from the average.) Delaware Bay, however, shows almost 4 times the average tons per trip, while none of the other regions or subregions deviates by more than 60% from the average.

TABLE 5-7. OIL TONNAGE PER TANKER OR BARGE TRIP IN FOUR REGIONS, 1974-77

Region or Subregion	Oil Movement Tons/10^6	Tanker and Barge Trips/10^3	Tons per Trip
NEW YORK			
Port of NY	551.7	591.8	932.2
LI Sound	105.7	45.4	2328.2
Hudson River	71.9	38.4	1872.4
DELAWARE BAY	413.4	75.0	5512.0
LOUISIANA COAST	1012.0	749.1	1350.9
N. TEXAS COAST	736.6	462.4	1593.0
	2891.3	1,962.1	1,473.7

It was estimated in Section 3 that about 80% of barge cargoes were oil, averaged over the U.S. Thus if, in a certain region, 100% of barge cargoes were oil, then its tons/barge trip figure would increase from the average by 25%. Similarly, if only 40% of barge cargoes were oil in a certain region, then its tons/barge trip figure would drop by 50%. The corresponding possible range of variation for tankers, which carry oil on 95% of their laden trips, on the average, is +5% and -58%. Therefore the +400%

variation from the average seen in Delaware Bay cannot be due to the mix of oil vs. other liquid cargoes, but can only be due to a substantially larger average tanker and barge cargo in Delaware Bay, or to a heavier percentage of tanker trips vs. barge trips in Delaware Bay. Neither supposition is borne out by an analysis of trips and drafts in Delaware Bay, compared to other port regions.* It seems likely, then, that there are substantial inaccuracies in the barge and tanker trips data employed for Delaware Bay.

Another possibly significant deviation from the mean spill rate is observed in Table 5-6 under the Port of New York subregion. The observation probability here is seen to be .03, employing the test method of Appendix F with normal approximation. This deviation is significant, by a small margin, if a 95% significance level is employed, as has been done in previous tests. When so close a margin of significance is involved it is advisable to employ an additional test for corroboration. This may be done by hypothesizing a uniform spill rate of .0385 spills per thousand trips, obtained from the total number of vessel-relates spills (74) and total number of barge and tanker trips (1,923,700) shown in Table 5-6. Thereupon, the expected number of vessel-related spills in the Port of New York is 22.8, based on the 591,800 tanker and barge trips for the sub-region shown in Table 5-6. The actually observed number of spills, however, is only 14, or about 8 spills less than expected. Assuming a Poisson distribution for the number of spills in the subregion leads to the conclusion that the probability is about .07 that an observation would differ from the expected 22.8 by as much as 9 spills, i.e., be as low as 14 or as high as 32. This approach, then, does not corroborate the results of the previous one, since it leads to only 93% level of significance instead of a 97% level. The deviation of spill rate in the Port of New York subregion, shown in Tables 5-5 and 5-6, then, can be considered of only marginal significance.

*The average self-propelled tanker draft in 1975 was about 27.9 feet in the Delaware River, 24.4 feet in New York Lower Entrance Channels, and 28.5 feet in the Mississippi River between New Orleans and the Passes.

5.4 OTHER SPILL RATES

Several possible spill rate calculations have been omitted because they offer less promise of insight into the spill process than the three treated above.

One spill rate calculation not performed is that of tanker spills (or barge spills) per tanker trip (or per barge trip). This has been omitted because the tanker-barge indicator in PIRS has been found to be unreliable, both in this and other studies (Reference 23). Considering the relatively small number of tanker and barge spills in the data in any one region, a rate calculation for tankers or for barges is subject to substantial errors if the barge/tanker breakout is not accurate. Any result would be suspect, and therefore no such calculations were made.

Another possible spill rate calculation is that of vessel-related spills per vessel trip, rather than per tanker and barge trip. This calculation was not made because trips of all vessels vary substantially from port to port and do not bear a fixed relation to tanker and barge trips. Expanding the vessel trips to include other than tankers would add many vessel trips (particularly ferries, and chemical or dry-cargo vessels) that bear no relation to oil spills. For this reason neither gross spills per vessel trip nor vessel-related spills per vessel trip were calculated.

Among other possible spill rates not here investigated are:

crude oil spills per ton of crude movement

heavy oil spills per ton of heavy oil movement

light oil spills per ton of light oil movement

spills per ton for individual years.

5.5 ANALYSIS OF SPILL RATES

The calculations of the previous subsections show that the spill rates in the four selected regions have no significant deviations from their expected values with one major exception,

the Hudson River subregion. A minor exception also occurs in the vessel-related spills per tanker and barge trip in Delaware Bay.

The extraordinarily high spill rates calculated for the Hudson River in 1974-77 appear in three cases:

- o gross spills per million ton of oil movement
- o vessel-related spills per million tons of oil movement
- o vessel-related spills per thousand barge and tanker trips.

Before concluding that the Hudson River subregion does, indeed, have a higher than normal number of spills, two other explanations must be explored:

a. Under-reporting of the exposure.

b. Over-reporting of the spills.

5.5.1 Under-reporting of Exposure

The two exposure variables involved are gross oil movement tonnage and tanker plus barge trips. The ACOE reporting of trips and of tons for domestic movements is done through the same mechanism, i.e., a single form. If both the trips and total tonnage were under-reported then this under-reporting probably occurred at the source, rather than in the compilation of statistics, because the spill rates derived from both variables are high. This possibility cannot be excluded because no alternate information source exists that may be used to verify the ACOE data.

A plot of Hudson River oil tonnage as reported by the ACOE by year is shown in Figure 5-1. If these data are under-reported, then the omissions must be consistent for each of the four years, particularly in the case of foreign and coastal light and internal heavy, which show little variation from year to year. Also, the crude movements are probably accurate because of the lack of refineries of any size in the Hudson valley. In short, if the spill rate anomalies for the Hudson River are due to under-reporting

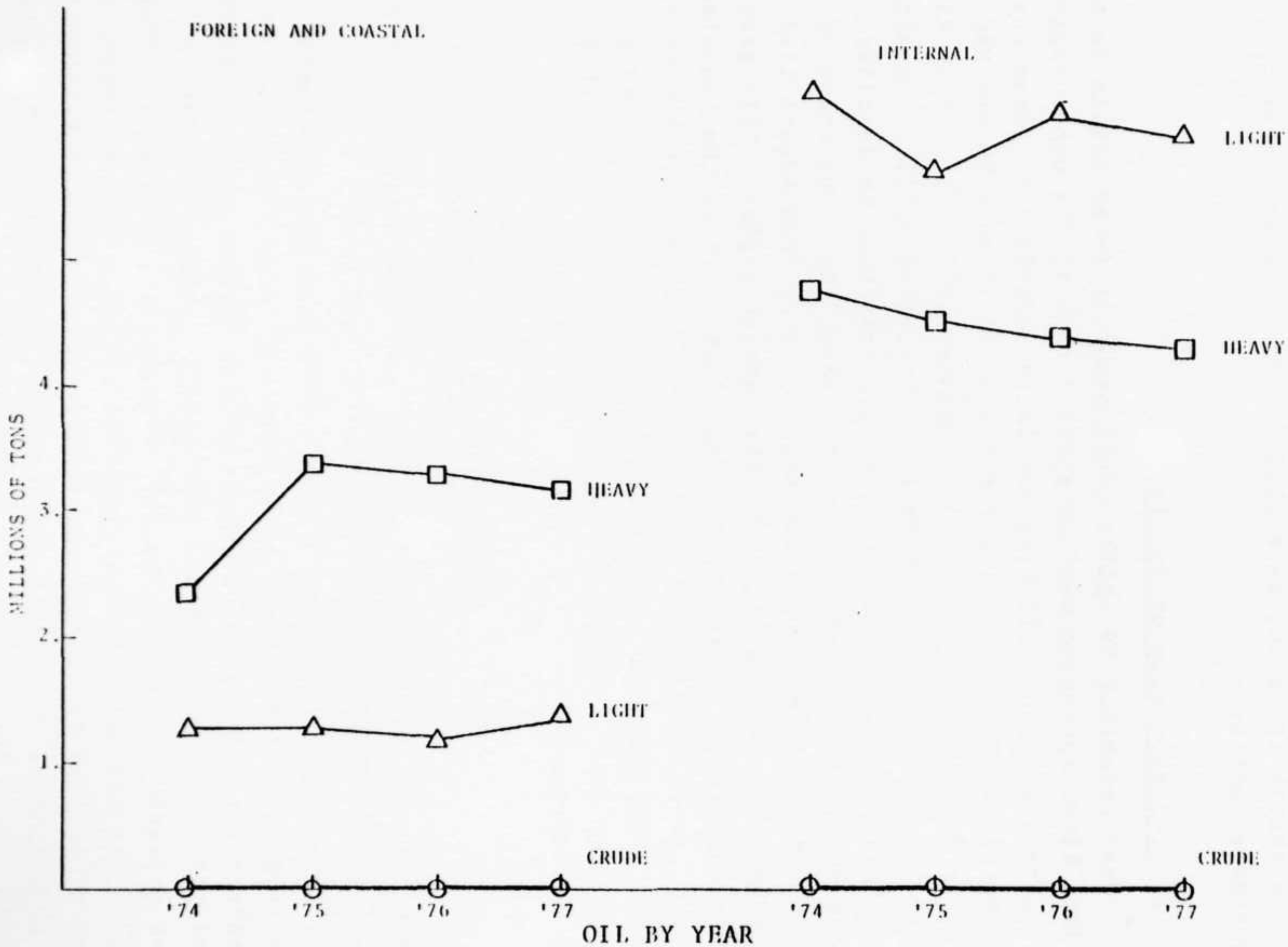

FIGURE 5-1. HUDSON RIVER OIL MOVEMENT, 1974-77, ACOE DATA

of oil movement, then there would have to have been a systematic under-reporting at the data origination point over the years 1974-77. Although it cannot be excluded such a systematic error is considered unlikely.

5.5.2 Over-reporting of Spills

Over-reporting of spills could occur if fewer spills in the Hudson River subregion went unreported than in the other regions or subregions. The following tabulation (Table 5-8) shows the estimated unreported spill percentages, based on PIRS and NRC reports from August 1974 through December 1977. The Hudson River does, indeed, have a low percent of unrecorded spills. In obtaining these percentages, the PIRS spills that bore no specific location other than the state were allowed for. One-third of the inland spills located by state and occurring from August 1974 to December 1977, were assigned to the nearest region. This gave 6.0 additional spills to the North Texas Coast, 1.3 to the Louisiana Coast, 1.0 to Delaware Bay, and 0.3 to New York. Since none of these spills involved vessels or marine facilities, no assignments were made for vessel-related spills. The percent unreported was calculated as

$$\frac{X \cdot Y/Z - (X + Y - Z)}{X \cdot Y/Z} \cdot 100$$

where X is the total of PIRS spills, Y is the total of NRC spills, and Z is the number reported by both.

In the next calculation (Table 5-9) the reporting factor was applied to total reported spills, including VCF spills, to obtain the total estimated spills in all regions and subregions in 1974-1977. One third of the PIRS spills recorded by state only were assigned, as before, to the corresponding regions in order to obtain the estimate of total reported spills. This estimate was then multiplied by 100/percent reported to obtain the total spill estimate. The spill rates obtained from the estimated total spills (Table 5-10), however, still show that the Hudson River

TABLE 3-8. ESTIMATED PERCENT UNREPORTED SPILLS, AUGUST 1974 - DECEMBER 1977

	PIRS(1)	PIRS State Only(2)	NRC	Both	Unreported Percent(3)
ALL SPILLS					
Port of NY	23	0.3	14	7	35%
LI Sound	3	0.0	2	1	33
Hudson River	13	0.0	4	4	0
Delware Bay	13	1.0	6	3	39
Louisiana Coast	42	1.3	32	18	26
N. Texas Coast	20	6.0	13	10	14
VESSEL-RELATED SPILLS					
Port of NY	9	0.0	5	3	27%
LI Sound	1	0.0	1	1	0
Hudson River	11	0.0	4	4	0
Delaware Bay	6	0.0	3	3	0
Louisiana Coast	18	0.0	16	10	17
N. Texas Coast	10	0.0	8	7	4

(1) PIRS spills with specific location in the region from Appendix A.

(2) PIRS spills without specific location, allocated 1/3 to adjacent region.

(3) Estimated unreported spills as percent of total of reported and unreported.

TABLE 5-9. TOTAL ESTIMATED SPILLS, ALL REGIONS, 1974-77

	PIRS and NRC[1]	VCF only	PIRS, State only	Total Reported	Total Estimated
ALL SPILLS					
Port of NY	36	2	0.3	38.3	58.9
LI Sound	6	0	0.0	6.0	9.0
Hudson River	19	0	0.0	19.0	19.0
Delaware Bay	21	1	1.0	23.0	37.7
Louisiana Coast	63	5	1.3	69.3	93.6
N. Texas Coast	32	2	9.0	43.0	50.0
VESSEL-RELATED SPILLS					
Port of NY	12	2	0.0	14.0	19.2
LI Sound	3	0	0.0	3.0	3.0
Hudson River	14	0	0.0	14.0	14.0
Delaware Bay	8	1	0.0	9.0	9.0
Louisiana Coast	27	5	0.0	32.0	38.6
N. Texas Coast	14	2	0.0	16.0	16.7

[1] See Tables 3-3, 3-4, 3-5, and 3-6.

TABLE 5-10: TOTAL ESTIMATED SPILL RATES, ALL REGIONS, 1974-77

	Estimated Spills	Exposure	Spill Rate
SPILLS PER MILLION TONS			
Port of NY	58.9	551.7	0.107
LI Sound	9.0	105.7	0.085
Hudson River	19.0	71.9	0.264
Delaware Bay	37.1	413.4	0.090
Louisiana Coast	93.6	1012.0	0.092
N. Texas Coast	50.0	736.6	0.068
	267.6	2891.3	0.093
VESSEL-RELATED SPILLS PER MILLION TONS			
Port of NY	19.2	551.7	0.035
LI Sound	3.0	105.7	0.028
Hudson River	14.0	71.9	0.195
Delaware Bay	9.0	413.4	0.022
Louisiana Coast	38.6	1012.0	0.038
N. Texas Coast	16.7	736.6	0.023
	100.5	2891.3	0.035
VESSEL-RELATED SPILLS PER 10^3 TANKER AND BARGE TRIPS			
Port of NY	19.2	591.0	0.032
LI Sound	3.0	45.4	0.066
Hudson River	14.0	38.4	0.365
Delaware Bay	9.0	75.0	0.120
Louisiana Coast	38.6	749.1	0.052
N. Texas Coast	16.7	462.4	0.036
	100.5	1962.1	0.051

has much higher spill rates than the other regions. Moreover, it appears that the North Texas Coast shows noticeably lower spill rates.

The significance of the spill rates of Table 5-10 is calculated in Table 5-11. The following results emerge:

a. The Hudson River has a significantly higher spill rate than other regions or sub-regions, even when unrecorded spills are allowed for. The significance levels for all three spill rates are above 99.9%.

b. The North Texas Coast shows a probability of .01 for the estimated spills in that region. This estimate (50 spills), however, includes a somewhat arbitrary assignment of one third of the PIRS spills located only by state.

c. Delaware Bay shows significantly more vessel-related spills than other regions, based on tanker and barge trips. But for the reasons outlined in 5.5.1, the Delaware Bay trip data for barges and tankers probably explain this phenomenon.

Of the three anomalies above, only that of the Hudson River indicates without doubt an aberration in spills per million tons of oil movement or per thousand tanker and barge trips. Accordingly, the causes of these high spill rates will be analyzed next.

5.6 HUDSON RIVER SPILLS

Since neither under-reporting of exposure nor over-reporting of spills is a likely explanation of the high spill rate for the Hudson River, one is led to analyze the spills themselves. The breakdown of Hudson River spills over 10,000 gallons from 1974 to 1977, as extracted from Appendix A, is shown in Table 5-12.

It appears that groundings and marine facilities account for an inordinate percentage of spills in the Hudson River. Accordingly, a comparison of rates for groundings, collisions (including

TABLE 5-11. SIGNIFICANCE TESTS FOR TOTAL ESTIMATED SPILLS, ALL REGIONS, 1974-77

	Estimated Spills	Exposure	Expected Spills	Expected Variance	Probability of Estimated
SPILLS PER MILLION TONS					
Port of NY	58.9	551.7	51.1	41.3	.22
LI Sound	9.0	105.7	9.8	9.4	.79
Hudson River	19.0	71.9	6.7	6.5	.0000
Delaware Bay	37.1	413.4	38.3	32.8	.83
Louisiana Coast	93.6	1012.0	93.6	60.9	.99
N. Texas Coast	50.0	736.6	68.2	50.8	.01
	267.6	2891.3			
VESSEL-RELATED SPILLS PER MILLION TONS					
Port of NY	19.2	551.7	19.2	15.5	.99
LI Sound	3.0	105.7	3.6	3.5	.40
Hudson River	14.0	71.9	2.5	2.4	.0000
Delaware Bay	9.0	413.4	14.4	12.3	.12
Louisiana Coast	38.6	1012.0	35.2	22.9	.48
N. Texas Coast	16.7	736.6	25.6	19.1	.04
	100.5	2891.3			
VESSEL-RELATED SPILLS PER 10^3 TANKER AND BARGE TRIPS					
Port of NY	19.2	591.0	30.3	21.2	.02
LI Sound	3.0	45.4	2.3	2.3	.65
Hudson River	14.0	38.4	2.0	1.9	.000
Delaware Bay	9.0	75.0	3.8	3.7	.007
Louisiana Coast	38.6	749.1	38.4	23.7	.97
N. Texas Coast	16.7	462.4	23.7	18.1	.10
	100.5	1962.1			

TABLE 5-12. ANALYSIS OF HUDSON RIVER SPILLS,(1) 1974-1977

	1974	1975	1976	1977	Total
Groundings	4	1	0	1	6
Collisions*	0	1	0	0	1
Weather	0	0	0	1	1
Marine facilities	2	1	1	2	6
Onshore facilities	2	1	0	0	3
Miscellaneous	0	1	0	1	2
	8	5	1	5	19

(1) See Appendix A for list of spills.

*Includes rammings.

rammings) and marine facility spills was made between all regions and the Hudson River. The results are summarized in Table 5-13, given as absolute number of spills in 74-77/spills per million tons in 74-77.

The six groundings shown in Table 5-13 for the Hudson River subregion are significantly higher than can be expected on the basis of the .006 groundings/million tons shown in that table for all regions together. The probability for six groundings in the Hudson River, given the average rate for all regions, is well under 1 in 10^{10}. Similarly, the probability of six marine facility spills in the Hudson River subregion is also under 1 in 10^{10}, given the average rate for all regions. These significance levels leave little doubt that there was a significantly higher rate of groundings and marine facility spills in the Hudson River subregion than in the other regions.

TABLE 5-13. COMPARISON OF GROUNDINGS, COLLISIONS AND MARINE FACILITY SPILLS IN HUDSON RIVER WITH OTHER REGIONS[1]

	Groundings	Collisions	Marine Facilities
Hudson River	6/.083	1/.014	6/.083
New York, exclusive of Hudson River	7/.011	3/.006	2/.003
Delaware Bay	1/.002	3/.007	2/.005
Louisiana Coast	4/.004	18/.017	0/.000
N. Texas Coast	0/.004	7/.009	2/.003
Total	18/.006	32/.011	12/.004

(1) The first number given is the number of spills, as extracted from Appendix A, and the second number gives the spills, per million tons of oil movement, 1974-77.

Groundings

The Commercial Vessel Casualty File was reviewed for groundings and other vessel casualties occurring in the Hudson River from 1974 through 1977, in order to determine the principal factors in these incidents. A synopsis of the eight casualties, taken from the Third District Marine Safety Office reports follows:

a. Barge HYGRADE NO. 32, grounding at the Maue Oil Terminal, Ossining, January 11, 1974. "The proximate cause of the casualty was that heavy ice conditions delayed the barge's arrival at the terminal and subsequent discharging, so that at 0130, the barge's draught exceeded the depth of the water at the terminal due to the falling tide, thus resulting in the barge sitting on the bottom and puncturing one of the cargo tanks."

b. Barge HYGRADE NO. 2, grounding off Magdelan Island, on July 19, 1974. The proximate cause of the casualty was an error in judgment on the part of the mate on watch, in that he relied

heavily on the use of radar as his means of navigation in heavy rain and fog, which resulted in straying out of the channel and grounding.

c. Barge B NO. 75, grounded on Diamond Reef, New Hamburg, November 15, 1974. "The proximate cause of the casualty was negligence on the part of the mate on watch in that he failed to allow sufficient distance between his tow and Diamond Reef Lighted Buoy LLN 1889."

d. Barge NEW LONDON, grounding near Con Hook Island, on February 5, 1974. "At approximately 0130, as the operator was unable to ascertain his position using radar, and searchlight due to the icing over the shoreline, icing over of navigational aids, and snow storm conditions, the tow went inside of the location of Buoy #21 (LLNR 1870) and touched bottom."

e. Tanker COLORADO, striking of unknown underwater object near Athens, March 29, 1975. Hole in Number 2 Port Tank noticed after reaching Mobile, AL.

f. Barge DELAWARE, struck Tappan Zee Bridge, on December 31, 1975. The tug barge struck the west pier of the west pass at about 0705 while under tow. Visibility was reduced to less than one-quarter mile by fog.

g. Barge ETHYL H. grounded and sunk about 300 yards south of Con Hook, on February 4, 1977. "The proximate cause of the casualty was a failure on the part of the operator of the MV MCALLISTER BROS. to accurately ascertain his position in the river with respect to the charted rock." Because the radar had been showing a great deal of ice return and the visibility was good, the operator was not using the radar.

h. Barge B.F.T. NO. 50, ice damage near Stuyvesant on January 11, 1977. "The proximate cause of the casualty was extreme cold and ice conditions in the Hudson River which resulted in the cracking of the hull of the T/B B.F.T. NO. 50. Ice in the Hudson River in this area ranged from 1.5 to 2.5 ft."

The major factors that appear from these incidents are that

(1) They predominantly involve barges rather than tankers. The proportion of barge incidents (7 out of 8) is not surprising, since about 80% of tank vessel trips in the Hudson are by barges. (See Appendix D).

(2) Weather was a factor in six of the eight incidents. It may be described as the major factor in two of the incidents (1., 6.) and appears to have been the only factor in two others (4. and 8.). The other major factor was piloting error. A breakdown (somewhat subjective) follows:

Incident #	Weather	Piloting	Other
1	✓		✓
2	✓	✓	
3		✓	
4	✓		
5			✓
6	✓	✓	
7	✓	✓	
8	✓		

Marine Facility
Spills

The six marine facility spills in the Hudson River subregion could not be investigated in any detail. None of these spills involved casualties, and hence had no casualty report; only one was recorded in the NRC files. The only information obtained for the remaining five was that of the PIRS files. The PIRS data contain no narrative report. The PIRS spill source and cause/factor codes, however, were as follows;

Incident	Source	Cause/Factor
1	101	Tank overflow/Improper valve operation
2	101	Natural or chronic phenomenon/Leaching from saturated ground
3	101	Valve Failure/PE-overpressurization
4	101	Tank rupture or leak/PE-overpressurization.
5	101	Improper equipment handling or operation/ Improper valve operation
6	101	Tank overflow/Improper valve operation.

The 101 source code indicates onshore bulk cargo transfer at a marine facility. Four of the six incidents occurred in port or harbor areas; one occurred in a river or channel or other restricted navigable waterway; and one occurred on a beach or shore adjoining a navigable waterway or tributary to navigable water.

The 8-digit source identifiers associated with the above incidents indicate that only three of the spills (1, 4 and 6) occurred during a transfer operation. It is not recorded whether a vessel was involved in the transfers. It may be conjectured that such was the case in spills 1 and 6, but probably not in 4.

Unlike the vessel incidents, it is difficult to select a predominant cause or pattern to the marine facility incidents. If any single cause is prevalent it is that of improper valve operation, which was cited as a factor in three of the six cases, and in both (possibly) vessel-related cases.

6. SUMMARY OF RESULTS

The results of this investigation have been developed from a data base of about 200 spills over 10,000 gallons in the period January 1974 through December 1977, (Appendix A). The data were extracted from the Pollution Incident Reporting System (PIRS), the National Response Center (NRC) files, and the Commercial Vessel Casualty File (VCF). In putting together this data base and in analyzing it, the following major results emerged:

a. Some spills are recorded in PIRS but not NRC, and vice-versa. From this, and certain assumptions on sampling, (Section 3) it is estimated that at least 13% and probably about 25% of all spills in 1974-77 went unrecorded by either PIRS or NRC. The percentages for vessel-related spills are about half of these. Pooling the PIRS and NRC data recording mechanisms would not increase the percent of spills recorded and would make it more difficult to estimate that percentage.

b. All four regions studied (New York, Delaware Bay, Louisiana Coast, North Texas Coast) had approximately the same number of spills per million tons of oil movement, with the exception of the Hudson River subregion of New York.

c. All four regions exhibited similar numbers of vessel-related spills per million tons of oil movement, with the exception of the Hudson River subregion.

d. When vessel-related spills per thousand tanker and barge trips were computed, it was found that only Delaware Bay and the Hudson River subregion have significantly different spill rates from the other regions. There is reason to believe, however, that the vessel trip data employed for Delaware Bay have substantial inaccuracies.

e. An apparently low spill rate for the North Texas Coast region can not be attributed any statistical significance because of the large number (27) of spills recorded in PIRS only by state (Texas, in this case), many of which could have occurred in the North Texas Coast region.

f. The high spill rates, of all three types tested, shown by the Hudson River subregion cannot be easily explained by either under-reporting of spills in the other regions (in so far as that could be estimated) or by under-reporting of the exposure variables.

g. The high spill rates in the Hudson River are largely due to (1) groundings of barges and (2) marine facility spills. The groundings and other vessel casualties were traced primarily to weather conditions (ice and fog) but no explanation could be found for the marine facility spills, except (perhaps) faulty valve operation.

APPENDIX A

OIL SPILLS OF 10,000 GALLONS OR MORE IN FOUR COASTAL REGIONS OF THE UNITED STATES 1974-1977

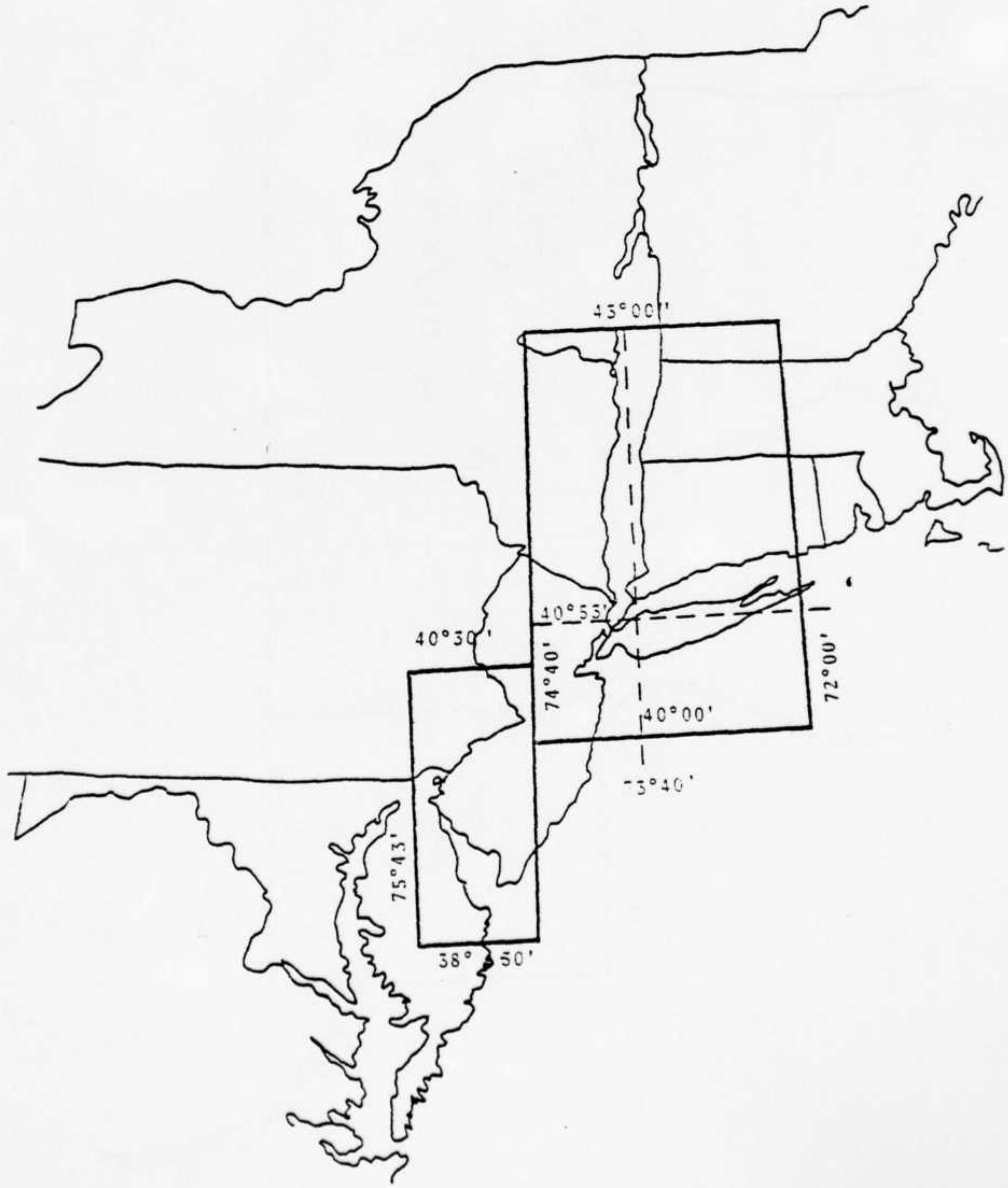

FIGURE A-1. GREATER NEW YORK AND DELAWARE BAY REGIONS

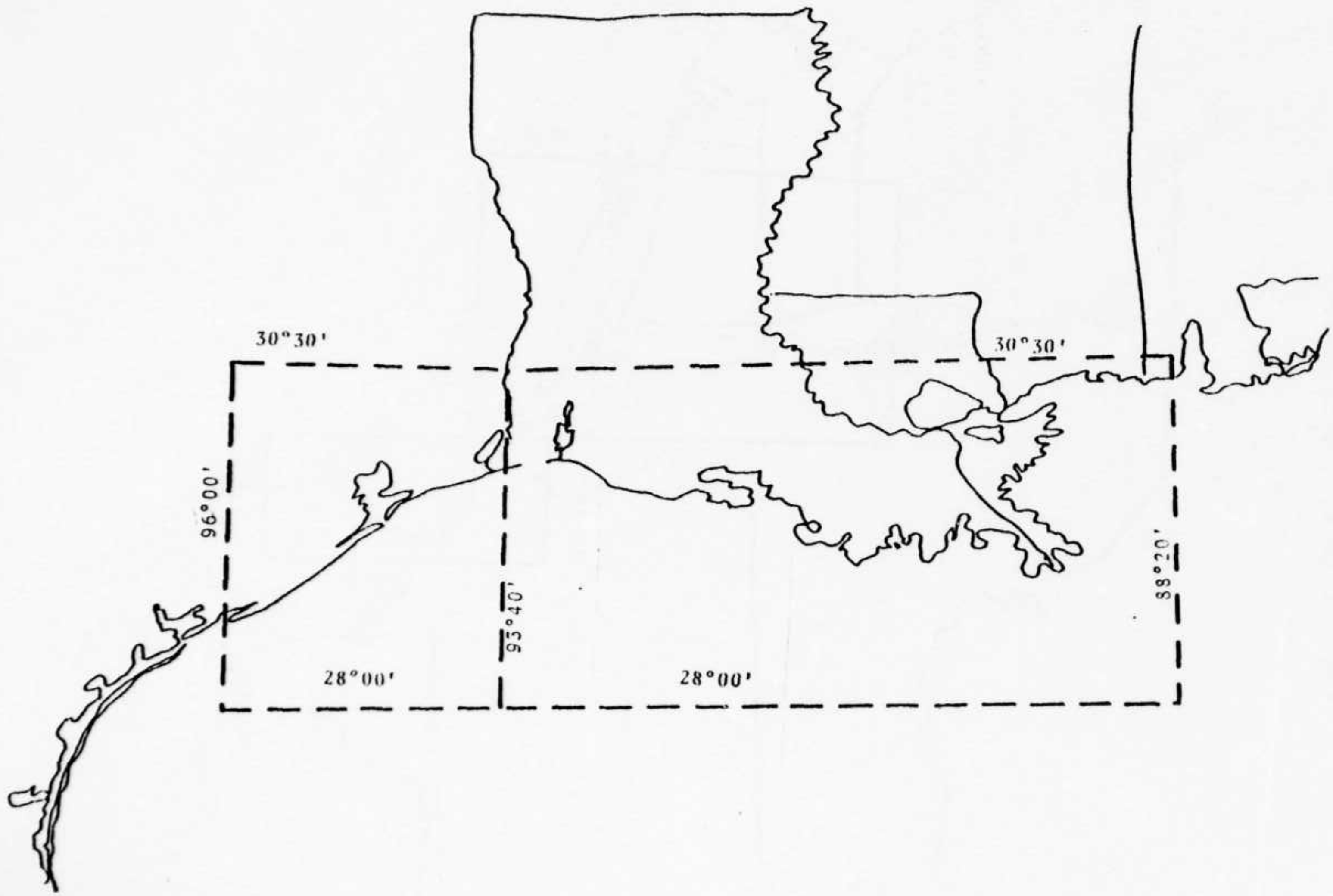

FIGURE A-2. LOUISIANA COAST AND NORTH TEXAS COAST REGIONS

OIL SPILLS OF 10000 GALLONS OR MORE
IN FOUR U S COASTAL REGIONS
1974 THROUGH 1977

COL 1 — TWO DIGITS EACH FOR YEAR, MONTH, DAY, HOUR FOLLOWED BY ONE DIGIT TO INDICATE MULTIPLE SIMULTANEOUS SPILLS AND ONE DIGIT TO INDICATE CARD NUMBER 1 OR 2.

COL 2 — LATITUDE AND LONGITUDE OR RIVER AND MILE, AS PER PIRS CODING MANUAL, CG-450, FEB 1976.

COL 3 — WATER BODY NAME, WHEN AVAILABLE.

COL 4 — NEAREST CITY, TOWN OR GEOGRAPHIC FEATURE.

COL 5-7 — CASE NUMBERS.

COL 1 DATE/TIME	2 LOCATION	3 WATER BODY	4 CITY/STATE		5 PIRS	6 NRC	7 VCF
NEW YORK REGION-1							
1974-1							
7401041301	L422507347	HUDSON RIVER	MILL CREEK	NY	0300018		
7401110101	L410907352	HUDSON RIVER	OSSINING	NY	0300034		42310
7401190601	L404707356	EAST RIVER	NEW YORK CTY	NY	0300075		41877
7401231001	L410207402	INLAND WATERWAY	MONTVALE	NJ	0300098		
7402030101	L412007358	HUDSON RIVER C-HK	HIGHLAND FLS	NY	0300147		42763
7402202401	L413107203	LONG ISLAND SOUND	NEW LONDON	CT	0300207		
7403111901	L403207415	ARTHUR KILL	PERTH AMBOY	NJ	0300281		
7403251601	L404307408	NEWARK BAY	NEWARK PORT	NJ	0300326		
7405052101	L403907407	KILL VAN KULL	BAYONNE	NJ	0300539		
7405061301	L403907410	NEWARK BAY	STATEN IS NY	NY	0300537		42824
7407011401	L403107414	PERTH AMBOY	TOTTENVILLE	NY	0300839		
7407141901	L410007305	LONG ISLAND SOUND	PORT JEFFRSN	NY	0300893		
7407190101	L420207356	HUDSON RIVER	MAGDALEN ISL	NY	0300921		50361
7407310801	L423507346	HUDSON RIVER	GLENMOUNT	NY	0300986	3-75	
7408041601	L403407353	ROCKAWAY INLET	FORT TILDEN	NY	0301012		
7408211201	L423707345	HUDSON RIVER	ALBANY	NY	0301110		
7410050901	L404707359	HUDSON RIVER	MANHATTANNYC	NY	0301285		
7410060101	L411807255	CONNECTICUT RIVER	NEW HAVEN	CT	0301289	114-75	52110

7411132301	L413507357	HUDSON RIVER	NEW HAMBURG	NY	0301437	179-75	51049
7412091101	L403007430	RARITAN RIVER	HIGHLAND PRK	NJ	0301633		
7412301501	L404407406	NEWARK BAY	JERSEY CITY	NJ	0301626	241-75	
1975-1							
7501070401	L404407356	NASSAU R NEWTONCR	LICY QUEENS	NY	0300026		
7501102301	L423707346	ISLAND CR HUDSONR	ALBANY	NY	0300043		
7503141001	L424507344	HUDSON RIVER	ALBANY	NY	0300300		
7503290901	L403707404	VARRAZANO NS HDSN	STATEN IS NY	NY	0300366	342-75	
7503291801	L423807344	HUDSON RIVER	ALBANY	NY	0300370	343-75	52859
7504090701	L424307342	HUDSON RIVER	ALBANY	NY	0300409		
7510071901	L404807354	EAST RIVER	BRONX NYCY	NY	0301274	485-75	62076
7511221001	L401007426	CROSSWICK CREEK	NEW EGYPT	NJ		517-75	
7512310701	L410507355	HUDSON RIVER NIAK	TARRYTOWN	NY	0301587	1-76	62093
1976-1							
7601042001	L404007358	GOWANUS CANAL	BROOKLYN	NY		3-76	
7602130011	L414507242	CONNECTICUT RIVER	HARTFORD	CT		44-76	
7602230011	L404607350	EAST RIVER	QUEENS NY	NY	0300209		
7603181901	L404907407	PASSAIC RIVER	RUTHERFORD	NJ	0300299		
7604010801	L403907407	KILL VAN KULL	BAYONNE	NJ	0300359		
7604170801	L411907254	CONNECTICUT RIVER	NEW HAVEN	CT	0300420		
7604302101	L403007420	ARTHUR KILL	PERTH AMBOY	NJ	0300476		
7605080011		UPR NEW YORK HRBR	ELLIS ISLAND	NY			62351
7605261701	L404407405	HACKENSACK RIVER	JERSEY CITY	NJ	0300588	134-76	
7606210401	L403507404	LOWER NEWYORK BAY	STATEN ISLND	NY	0300734		
7610052201	L404207409	NEWARK BAY	PORT NEWARK	NJ	0301230		
7610060011	L404007413	DRAINAGEDITCH	PORT ELIZABT	NJ		201-76	
7610100101	L425007345	HUDSON RIVER	ALBANY	NY	0301256		
7610230001	L403707339	MIDDLE BAY	OCEANSIDE	NY	0301310		
7610290221	L403207415	ARTHUR KILL	PERTH AMBOY	NJ	0301328	212-76	70771
7611301101	L402507414	WOODBRIDGE CREEK	CARTERET	NJ		7-77	
7612301101	L404007402	NEWYORK HARBOR	NEW YORK	NY		253-76	72379
1977-1							
7701021201	L423507345	ISLAND LR HUDSONR	ALBANY	NY	0300004		
7701030901	L404707403	HACKENSACK RIVER	SECAUCUS	NJ	0300014	12-77	
7701111201	L422207348	HUDSON RIVER	STUYVESANT	NY	0300022		
7702012001	L403207415	ARTHUR KILL	PERTH AMBOY	NJ	0300096		
7702041901	L412107357	HUDSON RIVER MP50	HILAND FALLS	NY	0300115	35-77	71547
7702271001	L403607340	REYNOLDS CHANNEL	LONG BEACH	NY	0300200		
7703050901	L404207402	MORRIS CANAL	JERSEY CITY	NJ	0300243	69-77	

7703070011		HEMPSTEAD HARBOR	NEW YORK	NY			71357
7704110801	L414007345	HUDSON RIVER	POUGHKEEPSIE	NY	0300373		
7705221501	L404907356	HARLEM RIVER	NEWYORK CITY	NY		103-77	
7706020201	L411807354	HUDSON RIVER	PEEKSKILL	NY	0300660		
7707171301	L411407256	CONNECTICUT RIVER	NEW HAVEN	CT	0300866		
7708130001		PLATTY KILL CREEK	BAYONNE	NJ		141-77	
7708260901	L404307407	NEWARK BAY	PORT NEWARK	NJ	0301113		
7709081701	L403907401	UPPER NEWYORK BAY	BROOKLYN	NY	0301227		
7709230011	L404907408	PASSAIC RIVER	LYNDHURST	NJ	0301952		
1974-77	LOCATION OR QUANTITY UNCERTAIN						
7402190011		CONNECTICUT RIVER	EAST HARTFRD	CT			42779
7409270011		SHINNECOCK	NEW YORK	NY			
7411090011		PORT RICHMOND	STATEN IS NY	NY			53131
7510111001				NJ	0301294		
7706150001		EAST RIVER	RAINEY PARK	NY		117-77	

DELAWARE BAY REGION-1

1974-1							
7401040801	L401007444	DELAWARE RIVER	BORDENTOWN	NJ	0300014		
7402051501	L403007530	INLAND	EMAUS	PA	0300954		42770
7402191201	L395107517	DELAWARE RIVER	PAULSBORO	NJ	0300195		
7404092201	L395307512	DELAWARE RIVER	PHILADELPHIA	PA	0300395	4-75	51363
1975-1							
7501310101	L394807525	DELAWARE RIVER	MARCUS HOOK	PA	0300151	288-75	52961
7504241901	L395407512	DELAWARE RIVER	PHILADELPHIA	PA	0300471		
7504030011		ATLANTIC OCEAN	112M OFF SHR				61974
7506171611	L392507528	SALEM RIVER	SALEM	NJ		400-75	
7506171621	L395807506	DELAWARE RIVER	CAMDEN	NJ	0300732		
7507280001	L400607452	DELAWARE RIVER	BRISTOL	PA		095-77	
7509140901	L395407512	DELAWARE RIVER	PHILADELPHIA	PA	0301162		
7511041201	L395107520	DELAWARE RIVER	CHESTER	PA	0301387		
1976-1							
7601021301	L394807525	DELAWARE RIVER	MARCUS HOOK	PA	0300010		
7602250101	L395407512	DELAWARE RIVER	WESTVILLE	NJ	0300214		
7604291501	L395307509	DELAWARE RIVER	GLOUCESTER C	NJ	0300474	120-76	62342
7607012201	L385207530	INLAND	STAYTONVILLE	NJ	0300962		
7609160001	L400007525	INLAND	HAVERFORD	PA		185-76	

7612051501	L395607513	DELAWR-SHYLKLL RV	PHILADELPHIA	PA	0301465		
7612281601	L394807525	DELAWARE RIVER	MARCUS HOOK	PA	0301555	247-76	77680
1977-1							
7701121001	L395707511	DELAWR-SHYLKLL RV	PHILADELPHIA	PA	0300042		
7701201301	L395807506	DELAWARE RIVER	CAMDEN	NJ	0300052		
1974-77 LOCATION OR QUANTITY UNCERTAIN							
7510031401		INLAND-102		PA	0301265		
7510310101		INLAND-102		PA	0301382		
7511221001		INLAND-102		NJ	0301462		
7612200011		DELAWARE RIVER	PAULSBORO	NJ			71185
7704090011		SHUYLKILL RIVER	PHILADELPHIA	PA			72873

LOUISIANA COAST REGION-1

1974-1							
7401101101	L294909015	LAKE SALVADOR	BARATARIA	LA	0804755		
7401152001	L300409145	GRAND LAKE EAST	MARTINVILLE	LA	0804824		
7401180801	R LM 01195	MISSISSIPPI RIVER	GOOD HOPE	LA	0801920		
7404190001	L294809129	BAYOU TECHE	IRISH BEND	LA	0801070		
7406221511	R LM 01050	MISSISSIPPI RIVER	NEW ORLEANS	LA	0804543		
7406221521	R LM 01061	MISSISSIPPI RIVER	NEW ORLEANS	LA		5-75	
7406300801		COASTAL		LA	0802997		
7408272201	R IW 02320	LAKE CHARLES	LAKE CHARLES	LA		56-75	
7409010801	L291708922	MISSISSIPPI RVR	GRAND PASS	LA	0802373	63-75	
7409101601	L293208835	GULF OF MEXICO	CHANDELEUR-I	LA		69-75	
7409160701		COASTAL		LA	0803663		
7410211801	R LM 01760	MISSISSIPPI RIVER	DONALDSVILLE	LA	0804046	134-75	51257
7412220201	L285309041	GULF OF MEXICO	ISL DERNIERS	LA		235-75	
7412241901	R LM 00883	MISSISSIPPI RIVER	MERAUX	LA	0804462	236-75	
1975-1							
7501291801	R LM 00870	MISSISSIPPI RIVER	MERAUX	LA	0800288	281-75	53259
7502170011	L292908943	LAKE WASHINGTON	PORT SULPHUR	LA		312-75	
7503120201	R LM 01255	MISSISSIPPI RIVER	GOODHOPE	LA	0800859	330-75	
7503301601	R LM 00260	MISSISSIPPI RIVER	BOOTHVILLE	LA	0801019		
7504160201	R LM 00850	MISSISSIPPI RIVER	MERAUX	LA	0801274	361-74	60130
7504251401	R LM 01020	MISSISSIPPI RIVER	NEW ORLEANS	LA	0801375	370-75	52579
7505201201	R LM 02280	MISSISSIPPI RIVER	BATON ROUGE	LA	0803865		

7507181101	L294009120	BAYOU TECHE	PATTERSON	LA		425-75	
7507190011		INTCWWY/WXLAKOUTL	CHANDELEUR	LA			61262
7508110201	L293309145	EASTCOTE BLANCHE	MARSH ISLAND	LA	0803891		
7508120801	L292708927	GULFOFMEXICO	COQUILLE BAY	LA		445-75	
7508120901		COASTAL-401		LA	0802912		
7508150101	L282509255	GULFOFMEXICO GC	100MSTH/GRLK	LA	0802760	444-75	60909
7509090901	L293308924	GULF OF MEXICO	COQUILLE BAY	LA	0803260	464-75	
7510161001	L293909200	VERMILION BAY	REDFISH PT	LA	0803699		
7511180001		GRAND LAKE	CAMERON PRSH	LA		514-75	
1976-1							
7602142201	L292508932	GULF OF MEXICO	BURAS	LA	0802119	42-76	
7602200411	R LM 01132	MISSISSIPPI RIVER	KENNER	LA	0802157		
7602241501	R LM 00888	MISSISSIPPI RIVER	MERAUX	LA	0802193	63-76	62881
7602290701	L290609111	GULF OF MEXICO	CAILLOU BAY	LA	0802228	71-76	
7603010101	L293809056	BAYOU BLACK	GIBSON	LA	0803001	70-76	
7603170401	L291409000	BAYOU RIGAUD	GRAND ISLE	LA	0803110	86-76	
760329		LAKE CHARLES	LAKE CHARLES	LA		092-76	
7604072201	L295909012	HOEYS CANAL	CHALMETIE	LA	0804072	101-76	
7604140011	R IW 01000	GULF INL WWY WHL	FRANKLIN	LA			71559
7604151701	L293209330	GULF OF MEXICO	OFF CAMERON	LA	0860411		
7604240021	R LM 02310	MISSISSIPPI RIVER	BATON ROUGE	LA			63298
7607081601	R LM 00962	MISSISSIPPI RIVER	NEW ORLEANS	LA	0807057	159-76	70384
7607121301	L290908920	MISSISSIPPI RIVER	GRAND PASS	LA		164-76	
7608190601	L283509115	GULF OF MEXICO	65MSTHMRGNCY	LA	0808175		
7609252001	R LM 00890	MISSISSIPPI RIVER	CHALMETTE	LA		187-76	
7610060011	R LM 00800	MISSISSIPPI RIVER	BRAITHWAITE	LA			72030
7610080601	L301109132	GRAND LAKE EAST	MARTINVILLE	LA	0810055		
7610190201	L284109216	GULF OF MEXICO	70MSTHGRANLW	LA	0810119		
7610221601	L290908920	EAST BAY	SO-WEST PASS	LA	0810146		
7612181001	L282109130	GULF OF MEXICO	90MSTHFRNKLN	LA	0812139		
1977-1							
7701210201	R LM 01269	MISSISSIPPI RIVER	GOOD HOPE	LA		021-77	
7702260601	R LM 02220	MISSISSIPPI RIVER	BATON ROUGE	LA		053-77	
7703010201	R LM 00080	MISSISSIPPI RIVER	PILOTSTOWN	LA	0803002		
7703311401	L302208855	GULF OF MEXICO	BILOXI	MS	0850336		
7704011101	R LM 02280	MISSISSIPPI RIVER	BATON ROUGE	LA	0804003		
7704231701	L295409202	INLAND BAYOU TIGR	HENRY	LA	0804146		
7705131301	L300409030	DRAINAGE DITCH	LAPLACE	LA		096-77	

7705000011	L285608923	GULF OF MEXICO	BOMSTHIN-ORL	LA	0805145		
7706141101	L291909000	BAY MELVILLE	GRAND ISLE	LA		113-77	
7706252201	R IW 00235	MISSISSIPPI RIVER		LA	0860633		
7707220011	R LM 00890	MISSISSIPPI RIVER	CHALMETTE-NO	LA			73600
7708050901	R IW 00550	GULF INL WWAY WHL	HOUMA	LA	0808022	128-77	
7708180601	R LM 01252	MISSISSIPPI RIVER	GOOD HOPE	LA	0808124		
7709130601	R LM 01154	MISSISSIPPI RIVER	RESERVE	LA		140-77	
7710181301	L291508849	GULF OF MEXICO	MAIN PASS	LA	0810084	150-77	
7711260301	R LM 00954	MISSISSIPPI RIVER	NEW ORLEANS	LA	0811177		
7712071101	L300709059	INLAND	PLATTENVILLE	LA	0812063		
7712151201	R LM 01816	MISSISSIPPI RIVER	DONALDSVILLE	LA	0812090		
1974-77	LOCATION OR QUANTITY UNCERTAIN						
7401010011		INLAND		LA	0802306		
7403301111		INLAND		LA	0802307		
7403301121		INLAND		LA	080 773		
7410130011	R IW 01740	GLF INLWWAY WHL	LAKE CHARLES	LA			51698
7501091201		INLAND-107		LA	0801092		
7501130011	R LM 01070	MISSISSIPPI RIVER	KENNER	LA			51586
7510120011		GULF OF MEXICO176	EUGENE ISLND	LA			61265
7601000011		GULF OF MEXICO		TX			61793
7602170011		GULF OF MEXICO		TX			61849
7605100011	R LM 00900	MISSISSIPPI RIVER	CHALMETTE	LA			70150
7610200021	R LM 01210	MISSISSIPPI RIVER	GOOD HOPE	LA			73429
7611130011		GULF OF MEXICO175	EUGENE ISLND	LA			70725

NORTH TEXAS COAST REGION-1

1974-1							
7401250001	L301509444	INLAND	KOUNTZE	TX	0800662		
7402021101	L295809351	SABINE LAKE	PORT NECHES	TX	0800034		
7403110001	L294409523	BRAYS BAYOU	HOUSTON	TX	0800499		
7403151701	L302809419	INLAND	BESSMAY	TX	0802212		
7403160001	L302309415	INLAND	BUNA	TX	0800511		
7404020601	L284209539	BROWN CEDAR CVT	MATAGORDA PA	TX	0800708		
7404290001	L304709426	GALVESTON BAY	BAYTOWN	TX	0801087		
7407082201	L293709500	GALVESTON BAY	RED BLUFF	TX	0803895	6-75	50547

7407210001	L295009357	SABINE LAKE	LAKEVIEW	TX	0801834		
7408051601	L300209359	NECHES RIVER	BEAUMONT	TX	0801956	11-75	
7408060001	L294509523	BRAYS BAYOU	HOUSTON	TX	0801949	18-75	
7410170001	L292209505	INLAND	ALTA LOMA	TX		137-75	
7412211001	L292209454	TC INDUSTRIAL CNL	TEXAS CITY	TX	0804435		
1975-1							
7501040601	L292409454	TC INDUSTRIAL CNL	TEXAS CITY	TX		245-75	
7501211201	L292009500	HIGHLAND BAYOU	TEXAS CITY	TX	0803906		
7504101901	L291509525	FLORES BAYOU	DANBURY	TX	0803842		
7505300011		GULF OF MEXICO	GALVESTON	TX			53136
7508111501	L293509528	CLEAR CREEK	FRIENDSWOOD	TX	0804644	443-75	
7510040601	L291909447	WEST BAY	GALVESTON IS	TX	0803504	479-75	
7511211101	L293409425	IWWY EAST BAY BYU	HIGH ISLAND	TX	0803976		
7512241801	L292209453	TC INDUSTRIAL CNL	TEXAS CITY	TX	0804325	541-75	
1976-1							
7601142301	L295909353	NECHES RIVER	PORT NECHES	TX	0860112		
7601271601	L300009359	NECHES RIVER	PORT NECHES	TX	0860114		
7603151001	L285609520	BRAZOS RIVER	FREEPORT	TX		85-76	
7605040301	L293009453	GALVESTON,BAY	SMITH POINT	TX	0830502	122-76	
7606280011		HOUSTON SHP CANAL	HOUSTON	TX			63232
7609260101	L295809351	SABINE LAKE	LAKEVIEW	TX	0860928	188-76	
7611290801	L292209454	GALVESTON BAY	SAN LEON	TX	0831120		
1977-1							
7703281301	L302009425	INLAND	FRED	TX	0887390		
7708091401	L285709522	GULF OF MEXICO	25MSTHFREPRT	TX	0830809		
7709191701	L294409505	HOUSTON SHIP CNL	DEERPARK	TX	0840912	143-77	
7710310401	L292109448	GALVESTON BAY	SMITH POINT	TX	0831036	154-77	
7711260201	L301509530	INLAND	CONROE	TX	0888082		
7712021911	L294309512	HOUSTON SHIP CNL	HOUSTON	TX	0840518	167-77	
1974-77	LOCATION OR QUANTITY UNCERTAIN						
7402280011				TX	0800378		
7403290011				TX	0800770		
7404190011				TX	0801071		
7405020801				TX	0805016		
7405220011		IWWY/HSTNSHPCANAL	HOUSTON	TX			42490
7406050011				TX	0802309		
7406200011				TX	0802506		
7406200021				TX	0801636		
7406211401				TX	0802511		

7406272301		TX	0802311	
7409190011		TX	0802343	
7409200011		TX	0802438	
7409260011		TX	0802498	
7409270301		TX	0803901	
7409280901		TX	0804540	
7410030011		TX	0802589	
7410170011		TX	0802665	
7410170901		TX	0804546	
7410240011		TX	0803230	
7410310011		TX	0803239	
7410310301		TX	0804547	
7411030011		TX	0804549	
7412080011		TX	0804551	
7412191001		TX	0804593	
7412230011		TX	0804574	
7501070301		TX	0801035	
7501071201		TX	0801079	
7501161001		TX	0801440	
7607060011	DUPONT TERL DOCKS BEAUMONT	TX		62491

COL 9 SOURCE TYPE CODE, AS PER PIRS CODING MANUAL CG-450.
COL 10 NAME OF SOURCE, WHEN AVAILABLE.
COL 11 IDENTIFICATION NUMBER OF SOURCE. THIS IS USUALLY VESSEL NUMBER, CALL SIGN OR OTHER NUMBER RECORDED IN PIRS FILE.
COL 12 CAUSE/FACTOR CODE LETTERS AND DESCRIPTION, ASSIGNED ACCORDING TO PIRS CODING MANUAL, CG-450.
COL 13 PIRS CODE FOR OIL TYPE.
COL 14 QUANTITY OF OIL SPILLED, IN THOUSANDS OF GALLONS, FOLLOWED BY LETTER INDICATING SOURCE OF ESTIMATE; P=PIRS, N=NRC, V=VCF. THE LETTERS LV, MV, HV INDICATE LIGHT, MEDIUM, AND HEAVY POLLUTION INDICATORS IN THE VCF COMPUTER FILE.

COL 8 DATE/TIME	9 SOURCE	TYPE	10 NAME	11 ID	12 CAUSE/FACTOR			13 OIL	14 QTY
NEW YORK REGION-2									
1974-2									
7401041302	502	ONS FACY		00000089	BK	TNKRPT		1022	19P
7401110102	034	TNK BARG	HBRTUG	ON267113	BB	TNKRPT	GROUNDG	1040	11P
7401190602	034	TNK BARG	(RVRTUG)	ON540064	AB	HLLRPT	GROUNDG	1052	34P
7401231002	500	ONS FACY		00000089	IC	PIPRPT	CURROSN	1050	20P
7402030102	034	TNK BARG	NEW LONDON	ON266528	AB	HLLRPT	GROUNDG	1050	10P
7402202402	101	ONS TRFR		07000044	WK	FLNGLK	ERROR	1041	42P
7403111902	035	TNK BARG		ON004408	AB	HLLRPT	GROUNDG	1061	10P
7403251602	900		SATURN	00000089	YC	NATURL	LEACHNG	1095	10P
7405052102	900	UNSPECFD		00000099	SK	TNKOFL	FLN/GLS	1099	92P
7405052102	900	TNK BARG	OILBARG-34	00000044	AE	HILRPT	CURROSN	1041	21P
7407011402	057	PUB VSSL		ON220307	BE	TNKRPT	SINKING	1050	30P
7407141902	036	TNK BARG		CSOOELMD	OL	FLNGFL	OVP/RSR	1052	21P
7407190102	034	TNK BARG	(TGCLTKHO)	ON270766	AB	HLLRPT	GROUNDG	1011	130P
7407310802	101	ONS TRFR		48644829	SG	TNKOFL	IMP/MTN	1022	940P
7408041602	054	PSR VSSL		ON251566	BE	TNKRPT	SINKING	1052	10P
7408211202	101	ONS TRFR		00079529	YC	NATURL	LEACHNG	1011	15P
7410050902	302	RWY FFAC		00000040	RP	EQPFLR		1052	32P
7410060102	015	FREIGHTR	MESSNKIBRG	CSOOSWYJ	AB	HLLRPT	GROUNDG		105P
7411132302	034	TNK BARG	T/B #75	ON529170	AB	HLLRPT	GROUNDG	1052	20P
7412091102	401	ONS PPL		00000046	CL	PPLRPT		1040	20P
7412301502	503	ONS PNT		00000029	XG	SABOTG	VANDALM	1001	15P

1975-2										
7501070402	503	ONS	PLNT		00040729	RP	EQPFLR		1011	20P
7501102302	999	UNK				ZZ			1097	10P
7503141002	503	ONS	PLNT		00000091	IC	PIPRPT	CORROSN	1022	12P
7503290902	017	TNK	SHIP	CASPN TRDR	CS005MQM	AF	HLLRPT		1001	10P
7503291802	015	TNK	SHIP	COLORADO	ON245104	AB	HLLRPT	COLLISN	1022	32P
7504090702	101	ONS	TRFR		00018929	ML	VLVFLR	OVRPRSR	1061	21P
7510071902	034	TNK	BARG	B#115	ON561792	AB	HLLRPT	GROUNDG	1050	102P
7511221002	401	ONS	PPLN		00021529	CQ	PPLRPT		1041	250N
7512310702	014	TNK	BARG	TBDELAWARE	ON537022	AA	HLLRPT	CO/FDOB	1040	90P
1976-2										
7601042002	502	OIL	TANK			BQ	TNKRPT		1050	2500P
7602130012	999	UNKNOWN				ZZ			1000	UNKN
7602230012	503	ONS	PLNT			DQ	DIKRPT	UNKNOWN	1080	10P
7603181902	503	ONS	PLNT		00000029	IP	PIPRPT		1040	30P
7604010802	000		VSSL			ZZ			1052	20P
7604170802	502	ONS	STFY		14218929	OP	FLGFLR		1040	30P
7604302102	508	NNT	PPLN			CQ	PIPRPT		1099	40P
7605080012	034	TNK	BARG	TB E-23	ON258944	AA	HLLRPT	CO/FLOB		MV
7605261702	502	ONS	STFY		00000029	BG	TNKRPT		1052	150P
7606210402	999	UNKNOWN				ZZ			1052	30P
7610052202	401	ONS	PPLN		00086129	IA	PPLRPT		1011	15P
7610060012	900	ONS	DUMP	DUMPING GR		YC	NATURL	LEACHNG	1022	500N
7610100102	101	ONS	TRSF		36301229	BM	TNKRPT	OVRPRSR	1011	150P
7610230002	502	ONS	STFY			SK	TNKOFL		1011	25P
7610290222	016	TNK	SHIP	RCHRDSAVER	CS005MTV	AB	HLLRPT	GROUNDG	1000	190N
7611301102	401	ONS	PPLN	PIPELINE	00038729	CQ			1022	80N
7612301101	034	TNK	BARG	TBTEXCO998	ON279964	BA	TNKRPT	COLLISN	1020	13N
1977-2										
7701021202	101	ONS	BKTR		00000029	TG	VLVLEK	IMP-OPN	1011	13P
7701030902	301	RWY	CGTR	CONRAIL YD	00000040	RP	EQPFLR		1040	25P
7701111202	034	TNK	BARG	#50TGFNRNR	ON537290	AG	HLLRPT	WEATHER	1021	15P
7702012002	034	TNK	BARG		ON535880	AB	HLLRPT	GROUNDG	1052	160P
7702041902	034	TNK	BARG	T-BETHYL-H	ON277709	BB	TNKRPT	GROUNDG	1052	420P
7702271002	502	ONS	STFY		00000029	BJ	TNKRPT	MTL-FLT	1040	90P
7703050902	502	ONS	STFY	RUPTUREDTK	00000029	YC	NATURL	LEACHNG	1040	150P
7703070012	051	FRT	BARG	MVAJMCALSR	ON238601	AA	HLLRPT	CO/SMOB		MV
7704110802	900	MIS	SRCE		000000000	IP	PIPRPT		1050	16P
7705221502	500	ONS	FCLY	APRTMTBLDG		WG	VALVLK	IMP-OPN	1050	10N
7706020202	101	ONS	CGTR		07508529	SG	TNKOFL	IMP-OPNN	1011	147P

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7707171302 500 ONS FACY             00000082 IH PIPRPT PIP-CUT 1040    50P
7708130002 503 ONS PLNT BAYON-INDY           ZZ UNKNWN               2000N
7708260902 101 ONS CGTR             28000029 BQ TNKRPT         1040    30P
7709081702 050 CRG SHIP             CS00908A WL ERROR          1052    10P
7709230012 304 HWY FLNG             00084029 BO TNKRPT CORROSN 1011    40P
1974-77  LOCATION OR QUANTITY UNCERTAIN
7402190012 034 TNK BARG BLULIN-108  ON272218 AB HLLRPT GROUNDG          LV
7409270012 053 FSG VSSL MV-HOOKER   ON298620 AB HLLRPT FOUNDRG          LV
7411090012 034 TNK BARG TB-RTC-200  ON176520 AQ HLLRPT EXP-FIR          LV
7510111002 500 ONS FACY                      SG TNKOFL IMP-OPN 1040    18P
7706150002 500 ONS FACY HEATINGPLT           IP PIPRDT                   N


DELAWARE BAY REGION-2
1974-2
7401040802 501 ONS REFY             49561129 BN TNKRPT         1022   600P
7402051502 500 ONS FACY             00000022 WK                1052    18P
7402191202 017 VESSEL   ATHOS                AA HLLRPT COLISN  1052   285P
7404092202 015 TANKER   MVELIAS GR  CSOOSZOP AC EXPLSN         1001    13P
1975-2
7501310102 018 TANKER   CORINTHOS   ON001916 AA HLLRPT CO/MDVS 1000   500P
7504241902 502 ONS FACY             00000029 YC LEACHG         1052    14P
7504030012 034 TNK BARG JANET C     ON532513 AA HLLRPT CO/FSVS
7506171612 502 TNK STRG             00000029 BN HLLRPT         1040    50N
7506171622 501 ONS REFY             00000029 BN TNKRPT         1040    11P
7507280002 503          SUPERIORZN  00000033 YC CHRONC LEACHNG 1080    97N
7509140902 501 ONS REFY             00040729 OD FLNFLR MAT/FLT 1052    60P
7511041202 052 TOW BOAT                      HD HLLRPT STR/FLR 1095    73P
1976-2
7601021302 101 ONS TRSF             00000029 YC NATURL LEACHNG 1001    30P
7602250102 101 ONS TRSF             00088329 SA TNKOFL INADSDG 1097    12P
7604291502 016 TNK SHIP TG241420    ON246993 AA HLLRPT CULIISN 1030    84P
7607012202 504 ONS PRFY             00000029 XA INTDCH SALVAGE 1011    14P
7609160002 500 SUB POOL                      YC SEEPAG         1080    80N
7612051502 503 ONS PLNT             00000029 IP PIPRPT         1052   110P
7612281602 016 TNK SHIP OLYMICGAMS  CS005MXW AB HLLRPT GROUNDG 1000   134P
1977-2
7701121002 999                               ZZ                1040    16P
7701201302 501 ONS RFNY             00019729 ZZ                1011    40P
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1974-77 LOCATION OR QUANTITY UNCERTAIN

7510031402	401	ONS	PPLN		00061129	CF	PPLRPT		1011	99P
7510310102	201	RWY	LQBK			BD	TNKRPT	OVR-TRN	1021	442P
7511221002	401	ONS	PPLN		00021529	CQ	PPLRPT		1021	250P
7612200012	014	TNK	SHIP	SSMOBLENRG	BRITISH	AA	HLLRPT	CO/FDOB		
7704090012	034	TNK	BARG	INTERSTATE	ON174769	AQ	HLLRPT	FIRE-XP		LV

LOUISIANA COAST REGION-2

1974-2										
7401101102	502	ONS	FACY		00079529	JP	HOSRPT		1011	120P
7401152002	033	TNK	BARG		ON264959	AA	HLLRPT	COLLISN	1000	158P
7401180802	401	ONS	PPLN			CQ	PPLRPT		1000	1680P
7404190002	401	ONS	PPLN		00000046	CQ	PPLRPT		1000	25P
7406221512	034	TNK	BARG		ON524331	AA	HLLRPT	COLLISN	1000	1008P
7406221522	034	TNK	BARG	ABC 2311	ON524332	AA	HLLRPT	COLLISN	1000	240P
7406300802	052	TUG	BOAT			HE	STRFLR	SINKING	1050	11P
7408272202	036	TNK2BARG				AA	HLLRPT	COLLISN	1000	23P
7409010802	999					ZZ			1041	14P
7409101602	402	OFS	PPLN		00079529	IP	PPLRPT		1000	53P
7409160702	506	OFS	PRFY		00000013	MP	VLVFLR	OTHER	1000	17P
7410211802	016	TANKER		ERCOLE	CSOOICLY	AB	HLLRPT	GROUNDG	1052	205P
7412220202	506	OFS	WELL		00066613	FQ	BLOOUT		1000	40P
7412241902	033	TNK	BARG		ON001339	SG	TNKOFL	VALVEOP	1000	63P
1975-2										
7501291802	034	TNK	BARG	TS-86(9VS)	ON286742	BA	TNKRPT	COLLISN	1001	63P
7502170012	999					ZZ			1000	65P
7503120202	401	ONS	PPLN		00000044	MP	VLVELK	VLVEFLR	1052	25P
7503301602	503	ONS	PLNT		00018929	CA	PPLRPT	COLLISN	1001	11P
7504160202	015	TANKER		STOLT-PINR	CSOO6ZRU	AA	HLLRPT	COLLISN	1050	23P
7504251402	035	TNK	BARG		CG002006	AA	HLLRPT	COLLISN	1001	210P
7505201202	402	OFS	PPLN		00000046	CI	PPLRPT	PPLDMGE	1040	114P
7507181102	03	TNK	BARG	BARG-7041		AA	HLLRPT	COLLISN	1000	13P
7507190012	034	TNK	BARG	MVSCORPION	ON256423	AA	HLLRPT	COLLISN		MV
7508110202	401	ONS	PPLN		00000013	CQ	PPLRQT		1000	13P
7508120802	504	ONS	PRFY		00005029	SE	TNKOFL	OVERFIL	1001	17P
7508120902	504	ONS	PRFY		00005029	SE	TNKOFL	OVR-FIG	1001	12P

7508150102	016	TANKEB		GLOBTKSNKY	CS00ZFPS	AA	HLLRPT	COLLISN	1000	840P
7509090902	506	OFS	PRFY		00005029	SE	TNKOFL	OVERFIL	1001	17P
7510161002	504	ONS	PRFY		00000013	FQ	WL/BLO	BLOWOUT	1095	2520P
7511180002	900	OIL	WELL	TEXACO		ZZ	UNKNWN			42N
1976-2										
7602142202	506	OFS	PRFY		00040713	CQ	PPLRPT		1001	56P
7602200412	000	UNK	VSSL			HA	STRFLR	COLLISN	1095	55P
7602241502	034	TNK	BARG	BARG SJT-4	ON263376	AA	HLLRPT	COLLISN	1001	16P
7602290702	402	OFS	PPLN		00040746	CA	PPLRPT	COLLISN	1001	21P
7603010102	034	TNK	BARG	T-B SULLY	ON501481	AC	HLLRPT		1001	59P
7603170402	506	OFS	PRFY	(OIL/WTRSE	00023629	RP	VLVFLR		1001	40P
760329	401	ONS	PPLN						1052	42N
7604072202	500	ONS	STTK			OF	FLNFLR	IMPINST	1089	32P
7604140012	034	TNK	BARG	T-B S 1511	512033	AA	HLLRPT			MV
7604151702	401	ONS	PPLN			ID	PPLRPT	MAT/FLT	1095	21P
7604240022	034	TNK2BARG		T-B D+D1	509077	AA	HLLRPT	COLLISN		MV
7607081602	034	TNK	BARG	(#501485)	ON268387	WK		COLLISN	1051	84P
7607121302	502	ONS	BKST	(TANKFARM)	00040729	MP	VLVFLR		1001	39N
7608190602	000	UNK	VSSL		ON512387	SE	TNKOFL	OVERFIL	1040	10P
7609252002	01	L	VSSL	AMELIAGRML		KP	MFDRPT		1001	21P
7610060012	034	TNK	BARG	MVJMRIVERS	ON528629	AB	HLLRPT	GROUNDG		
7610080602	506	OFS	PRFY		00088313	CO	PPLRPT	CORROSN	1001	40P
7610190202	506	OFS	PRFY		00018913	ZZ			1040	13P
7610221602	506	OFS	PRFY		00069013	HQ	STRFLR		1001	11P
7612181002	506	OFS	PRFY		00069013	CO	PPLRPT	CORROSN	1001	55P
1977-2										
7701210202	03	TNK	BARG	BG NMS2600		AA	HLLRPT	COLLISN	1062	63N
7702260602	03	TNK	BARG	TB DXE29		AB	HLLRPT	COLLISN	1001	14N
7703010202	999					ZZ			1001	11P
7703311402	999					ZZ			1061	14P
7704011102	033				ON512720	AQ	HLLRPT		1050	21P
7704231702	401	ONS	PPLN		00088313	CO	PPLRPT	CORROSN	1001	50P
7705131302	503	ONS	STFY	GENRTNG ST	00000049	PP	GSKFLR		1040	20N
7705000012	000					ZZ	UNKNWN			

7706141102	401	ONS	PPLN	PIPELINE	00018929	CQ	PPLRPT		1001	176N
7706252202	034	TNK	BARG		ON502508	BA	TNKRPT	COLLISN	1052	168P
7707220012	01	TNK	SHIP	MVDCLCTRNS	GREEK	BA	TNKRPT	CO/FLDB		HV
7708050902	034	TNK	BARG	TBDELAWARE	ON260860	BA	TNKRPT	COLLISN	1041	63P
7708180602	034	TNK	BARG		ON269492	SK	TNKOFL		1052	17P
7709130602	01	TNK	SHIP	ATLTICMARQ	CSOOELOE	BA	TNKRPT	COLLISN	1001	74N
7710181302	402	OFS	PPLN	PIPELINE	00018929	CO	PPLRPT	CORROSN	1001	13P
7711260302	034	TNK	BARG		ON523761	BA	TNKRPT	COLLISN	1040	84P
7712071102	502	ONS	STFY		00000029	DQ	DIKRPT	DSGNFLT	1099	42P
7712151202	502	ONS	STFY		00000029	CO	PPLRPT	CORROSN	1001	11P

1974-77 LOCATION OR QUANTITY UNCERTAIN

7401010012	504	ONS	PRFY		00023646	IH	PIPRPT	PIP-CUT	1000	32P
7403301112	401	ONS	PPLN		00007946	CA	PPLRPT	COLLISN	1000	15P
7403301122	401	ONS	PPLN		00007929	CF	PPLRPT	OTHER	1000	15P
7410130012	034	TNK	BARG	MVTH-HINES	ON263149	AB	HLLRPT	GROUNDG		LV
7501091202	502	ONS	STFY		00000029	XG	INTDCH	SAB-VAN	1000	13P
7501130012	034	TNK	BARG	CABIBE-71	ON176172	BB	HLLRPT	GROUNDG		LV
7510120012	057	RES	OCVL	MVIBERIA	ON272753	AA	HLLRPT	CORIGWR		LV
7601000012	014	OSPLVSSL		MVBRTLCNDS	ON554083	AA	HLLRPT	COLLISN		LV
7602170012	034	TNK	BARG	OFSHRFULER	ON502611	AA	HLLRPT	CORGSTM		LV
7605100012	015	TANKER		MVMINILILY	GREEK	BA	HLLRPT	CORGNYRR		LV
7610200022	015	TANKER		GEORGEPRNC	ON236825	AA	HLLRPT	COLLISN		
7611130012	057	COM	SYVL	MVMRGNCTYS	ON548778	AA	HLLRPT	CO/FLDB		

NORTH TEXAS COAST REGION-2

1974-2

7401250002	401	ONS	PPLN		00000046	CF	PPLRPT		1000	99P
7402021102	015	TANKER			CSOOELVD	XA	INTDSC	BLGPMPG	1000	17P
7403110002	401	ONS	PPLN		00000046	CQ	PPLRPT		1011	63P
7403151702	401	ONS	PPLN		00008513	CQ	PPLPPT		1099	13P
7403160002	401	ONS	PPLN		00008529	CQ	PPLRPT		1099	13P
7404020602	506	OFS	PRFY		00000013	BD	TNKRPT	OVERTRN	1040	10P
7404299902	401	ONS	PPLY			CA	PPLRPT	COLLISN	1000	176P
7407082202	034	TNK	BARG	T/B TM-10	ONS17243	AA	HLLRPT	COLLISN	1052	378P
7407210002	034	TNK	BARG		ON541952	AA	HLLRPT	COLLISN	1052	84P
7408051602	401	ONS	PPLN		00800046	CQ	PPLRPT		1011	84P

7408060002	502	ONS	STFY		00020713	SK	TNKOFL		1011	42P
7410170002	401	ONS	PPLN		00004929	CA	PPLRPT	COLLISN	1011	21P
7412211002	034	TNK	BARG		ON263278	AJ	HLLRPT	MAT-FLT	1040	18P
1975-2										
7501040602	401	ONS	PPLN		00088429	CQ	PPLRPT		1000	2100P
7501211202	999	UNKNOWN			000	ZZ			1097	13P
7504101902	504	ONS	PRFY		00000046	HQ	STRFLR		1000	19P
7505300012	050	CRG	SHIP	SSALKESDMR	LIBERIAN	AA	HLLRPT	COLLISN		MV
7508111502	402	OFS	PPLN		00084029	IC	PPLRPT	CORROSN	1000	21P
7510040602	011	TNK	BARG	BARGE #663	CG017863	AE	HLLRPT	SINKING	1040	12P
7511211102	504	ONS	PRFY		00000013	TG	VLVELK	IMP-OPR	1001	27P
7512241802	017	TANKER		AMOCO-YKTN	CS005LBI	LH	LDGARM	SEVERED	1000	77P
1976-2										
7601142302	502	ONS	STFY		13220713	XG	INTDCH	SAB/VAN	1099	46P
7601271602	052	TUG	BOAT		ON263176	XH	INTDCH	SALVAGE	1040	10P
7603151002	102	ONS	STTK		00000027	OP	FLNFLR			11N
7605040302	015	TNK	SHIP	TBNMS 3105	ON567123	AQ	HLLRPT		1052	210P
7606280012	034	TNK	BARG	TBEXXON257	ON176709	AA	HLLRPT	CO/TXSN		1 E
7609260102	036	TNK	BARG	T/BSTCO225	ON569830	BA	TNKRPT	COLLISN	1000	42P
7611290802	401	ONS	PPLN		00004929	CJ	PPLRPT	MAT-FLT	1011	168P
1977-2										
7703281302	401	ONS	PPLN		00004929	CJ	PPLRPT	MAT-FLT	1011	17P
7708091402	000					IA	PPLRPT	MINORDG	1000	20P
7709191702	101	ONS	TRSF	SHIP TRMNL	00000029	TG	VLVELK	IMP-OPN	1040	17P
7710310402	034	TNK	BARG	TBSTCO-213	ON527979	AA	HLLRPT	COLLISN	1052	42P
7711260202	504	ONS	PRFY		00000029	IC	PIPRPT	CORROSN	1001	17P
7712021922	016	TNK	SHIP		CS005MPH	WK	HOSLK	ERROR	1000	38P
1974-77 LOCATION OR QUANTITY UNCERTAIN										
7402280012	504	ONS	PPFY		00044829	MP	VLVFLR	UNKNOWN	1000	40P
7403290012	401	ONS	PPLN		00000046	CQ	PPLRPT	UNKNOWN	1000	17P
7404190012	401	ONS	PPLN		00000046	CQ	PPLRPT	UNKNOWN	1000	21P
7405020802	504	ONS	PRFY		00000013	IC	PIPRPT	CORROSN	1000	21P
7405220012	034	TNK	BARG	TBELLIS554	ON253303	AA	HLLRPT	COL/GRD		LV
7406050011	504	ONS	PRFY		00008546	IC	PIPRPT	CORROSN	1000	21P
7406200012	504	ONS	PRFY		00008546	IH	PIPRPT	PIP-CUT	1000	13P
7406200022	401	ONS	PPLN		00000046	CA	PPLRPT	CULLISN	1000	21P
7406211402	401	ONS	PPLN		00000046	CA	PPLRPT	COLLISN	1000	15P
7406272302	401	ONS	PPLN		00044846	CJ	PPLRPT	MAT-FLT	1000	33P
7409190012	504	ONS	PRFY		00004913	BG	TNKRPT	WEATHER	1000	23P

7409200012	504	ONS	PRFY		00000013	RA	EQPFLR	COLLISN	1000	21P
7409260012	504	ONS	PRFY		00000013	MP	VLVFLR	UNKNOWN	1000	12P
7409270302	504	ONS	PRFY		00000013	MP	VLVFLR	UNKNOWN	1000	12P
7409280902	401	ONS	PPLN		00023646	CQ	PPLRPT	UNKNOWN	1000	29P
7410030012	401	ONS	PPLN		00000029	NP	PMPFLR	UNKNOWN	1000	25P
7410170012	401	ONS	PPLN		00004946	CA	PPLRPT	COLLISN	1011	21P
7410170902	401	ONS	PPLN		00004946	CA	PPLRPT	COLLISN	1095	19P
7410240012	502	ONS	STFY		00000029	XG	PIPRPT	IMP-MTN	1095	40P
7410310012	401	ONS	PPLN		00000046	CN	PPLRPT	COLLISN	1000	11P
7410310302	501	ONS	RFRY		00000029	IL	PIPRPT	OVR-PRS	1000	11P
7411030012	999	UNKNOWN			00000091	MJ	VLVFLR	IMP-OPN	1097	20P
7412080012	999	UNKNOWN			00070029	ZZ	UNKNWN	UNKNOWN	1097	17P
7412191002	401	ONS	PPLN		00000046	CQ	PPLRPT	UNKNOWN	1011	25P
7412230012	401	ONS	PPLN		00050946	CQ	PPLRPT	UNKNOWN	1000	15P
7501070302	401	ONS	PPLN		00084046	CQ	PPLRPT	UNKNOWN	1000	210P
7501071202	401	ONS	PPLN		00084046	CQ	PPLRPT	UNKNOWN	1000	210P
7501161002	401	ONS	PPLN		00084046	CL	PPLRPT	ERROR	1000	59P
7607060012	015	TNK	SHIP	SSOCEANCHT	ON4782LI	AA	HLLRPT	COLLISN		LV

LIST OF ABBREVIATIONS

BARG = BARGE

BK = BULK

BLG = BILGE

BLO = BLOW (IN BLOWOUT)

CG (CRG) = CARGO

CO = COLLISN - COLLISION

CDH = DISCHARGE

CG = DMGE = DAMAGE

DIK = DIKE (DYKE)

EQP = EQUIPMENT

EXP = EXPLOSION

FCLY = FY = FACILITY

FD = FIXED

FIR = FIRE

FL = FLOATING

FLN = FLNG = FLANGE

FLR = FAILURE

FLT = FAULT

FUNG = FUELLING

FY = FCLY = FACILITY

GSK = GASKET

HBR = HARBOR

HLL = HULL

HOS = HOSE

HWY = HIGHWAY

IMP = IMPROPER

INT = INTENTIONAL

LDG ARM = LOADING ARM

LEACHING = LEACHING

LK = LEK = LEAK

LQ = LIQUID

MAT = MATERIAL

MD = MOORED

MFD = MANIFOLD

MIS = MISCELLANEOUS

MTN = MAINTENANCE

NATURL = NATURAL

OB = OBJECT

OC = OCEANOGRAPHIC

OFL = OVERFLOW

OFS = OFFSHORE

ONS = ONSHORE

OPN = OPERATION

OVERTRN = OVERTRN

OVR = OVER

PIP = PIPE

PLNT = PLANT

PMP = PUMP

PPL = PPLN = PIPELINE

PR = PRODUCTION

PRS = PRESSURIZATION

RES = RESEARCH

RPT = RUPTURE

RWY = RAILWAY

SAB = SABOTGE = SABOTAGE

SDG = SOUNDING

SM = SUBMERGED

SRCE = SOURCE

ST = STRG = STORAGE

STR = STRUCTURAL

TK = TNK = TANK

TR = TRFR = TRANSFER

TRMNL = TERMINAL

VAN = VANDALISM

VL = VSL = VESSEL

VLV = VLVE = VALVE

WR = WEATHER

XSV = EXCESSIVE

APPENDIX B

ESTIMATION OF THE NUMBER OF OIL SPILLS WITH INFORMATION FROM TWO SOURCES

If 1,000 tagged trout are released into a lake in the spring, then the total trout population of the lake may be estimated by noting the fraction of tagged trout among all trout caught during the ensuing weeks. See Figure B-1. If, say, 5% of the specimens caught bear tags, then the population of trout may be estimated as approximately 20,000. This technique is subject to obvious errors, produced by such conditions as (1) unknown changes in the trout population, and (2) a non-representative sample being caught.

A modification of this technique may be used to estimate the true number of actual oil spills occurring over a period of time from the number reported through the USCG Pollution Incident Reporting System (PIRS) and through the National Response Center (NRC). Since the spills recorded by these two sources in 1974-77 have only a partial overlap, the true number of spills must be greater than reported by either. It can be estimated by applying elementary probability theory to some plausible assumptions, to be stated in what follows. As in the case of game population estimation, the method is subject to obvious qualifications.

CASE I, INDEPENDENT REPORTING

In the first case, it will be assumed that the two sources report randomly and independently. The probability

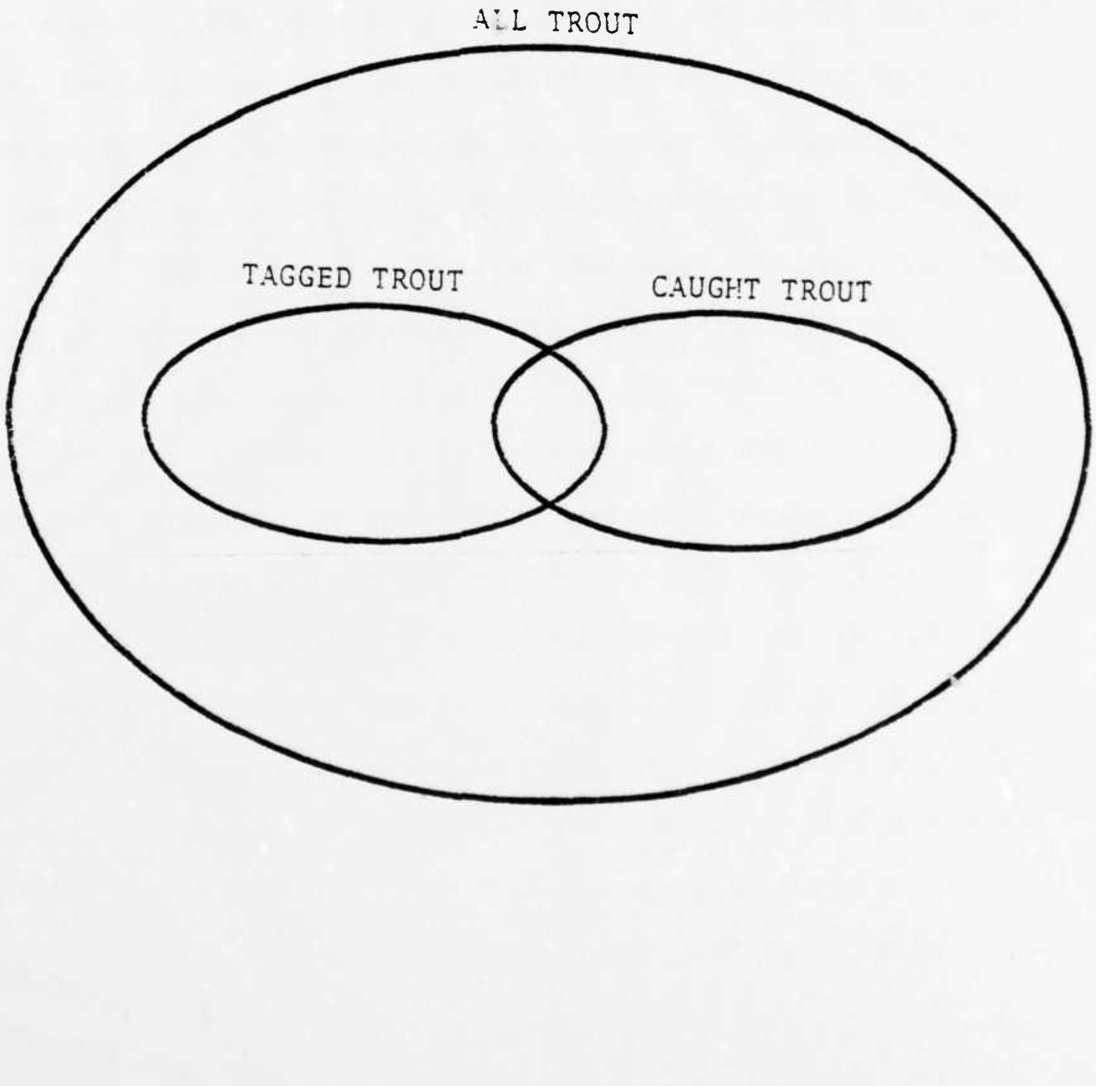

FIGURE B-1. POPULATION ESTIMATION TECHNIQUE

AD-A103 430 TRANSPORTATION SYSTEMS CENTER CAMBRIDGE MA F/G 13/2
A STUDY OF OIL SPILL RATES IN FOUR U.S. COASTAL REGIONS.(U)
JUN 80 J F BELLANTONI
UNCLASSIFIED TSC-USCG-80-3 USCG-D-26-81 NL

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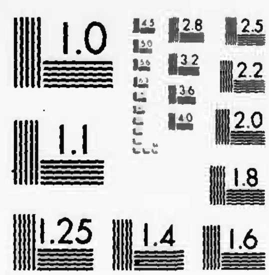

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

that the first source records a spill, given that one has occurred, is assumed to be a constant P_1. Similarly, the probability that the second source records a spill, given that one has occurred, is assumed to be a constant, P_2. If a total of N spills occur, then the number recorded by the first source will be N_1, and that by the second will be N_2:

$$N_1 = P_1 N, \tag{B-1}$$

$$N_2 = P_2 N; \tag{B-2}$$

and the number recorded by both will be N_3:

$$N_3 = P_1 P_2 N. \tag{B-3}$$

This last equation depends upon the assumption of independent recording.

From (1), (2) and (3), one may estimate the probabilities P_1 and P_2,

$$P_1 = N_3/N_2 \tag{B-4}$$

$$P_2 = N_3/N_1 \tag{B-5}$$

and the total number of spills that occurred, N, as

$$N = N_1 N_2 / N_3. \tag{B-6}$$

CASE 2, NON-INDEPENDENT REPORTING

If the reporting sources influence one another then the above analysis does not apply. Moreover, the problem cannot be solved with only the data N_1, N_2 and N_3 as above; its solution depends on additional parameters which often are more difficult to obtain.

Five mutually exclusive events can occur, if an oil spill is recorded:

A: Source 1 records the spill, and source 2 does not

B: Source 2 records the spill, and source 1 does not

C: Source 1 records the spill, and source 2 obtains its record from source 1

D: Source 2 records the spill, and source 1 obtains its record from source 2

E: Both sources record the spill independently.

The number N_1 of spills recorded by source 1 is calculated in terms of these events as:

$$\begin{aligned} N_1 &= N\ P(A+C+E+D) \\ &= N\ P(A+C+E) + N\ P(D) \\ &= N\ P_1 + N\ P_{1/2} P_2 \end{aligned} \tag{B-7}$$

where P(X+Y) indicates the probability of events X or Y; P_1 and P_2 are the probabilities of independent recording introduced before; $P_{1/2}$ is the probability that source 1 obtains its record from source 2, given that source 2 has obtained its data independently; and N is the total number of spills that occur. Similarly, the number of spills recorded by source 2 is:

$$N_2 = N\ P_2 + N\ P_{2/1} P_1, \tag{B-8}$$

where $P_{2/1}$ is the probability that source 2 obtains its record from source 1, given that source 1 has obtained its record independently. Finally, that number of spills that are contained in the records of both sources is N_3:

$$N_3 = N\ P(C+E+D)$$
$$= N\ P(C) + N\ P(E) + N\ P(D)$$
$$= N\ P_{2/1}P_1 + N\ P_1P_2 + N\ P_{1/2}P_2 \quad \text{(B-9)}.$$

It will be noticed that equations (7), (8) and (9) reduce to (1), (2) and (3) when $P_{1/2}$ and $P_{2/1}$ are zero. These two new probabilities are difficult to determine, and inject a degree of uncertainty into the estimates of P_1 and P_2 and N. Nevertheless, the following expressions for P_1, P_2 and N, having $P_{1/2}$ and $P_{2/1}$ as parameters, will prove useful.

$$P_1 = N_3'/N_2', \qquad \text{(B-10)}$$
$$P_2 = N_3'/N_1', \qquad \text{(B-11)}$$
$$N = N_1'/N_2'/N_3', \qquad \text{(B-12)}$$

where

$$N_1' = (N_1 - P_{1/2}N_2) \ / \ (1-P_{1/2}P_{2/1}),$$

$$N_2' = (N_2 - P_{2/1}N_1) \ / \ (1-P_{1/2}P_{2/1}),$$

$$N_3' = N_3 - P_{1/2}N_2' - P_{2/1}N_1' .$$

Again, one notices that these equations reduce to the previous ones when $P_{1/2}$ and $P_{2/1}$ are zero. If one assumes, for simplicity, that $P_{1/2}=P_{2/1} = \tau$ where τ is a constant that will be termed the transfer probability, then it is possible to calculate, as a function of τ the probabilities P_1 and P_2 of independent recording, and also the probability P_3 that a spill will be recorded by either collection agency, i.e.,

$$P_3 = P_1 + P_2 - P_1P_2. \qquad \text{(B-13)}$$

The results of these calculations are shown in Table B-1. The results are there tabulated as a function of τ, of the ratio N_1/N_2, and of the ratio λ,

$$\lambda = N_3/(N_1+N_2-N_3),$$

which is the fraction of reported spills that appear in the records of both sources. The quantity of ultimate interest, however, is P_3, the fraction of all spills that are recorded in either source. This fraction is plotted in Figure B-2 as a function of the transfer probability $\tau(=P_{1/2}=P_{2/1})$, with the overlap fraction λ as a parameter. The revealing aspect of these curves is that the recording probability decreases as the transfer probability increases, for a given fractional overlap. Moreover, the transfer probability can never exceed the overlap fraction. These limits on the transfer probability are seen in Figure B-2 as the points on the horizontal axis at which the recording probability goes to zero.

QUALIFICATIONS

The qualifications on trout population estimation apply to oil spills as well.

First, there is the assumption that one is dealing with a stable spill process. This is not a serious qualification if the estimates are taken to apply only to the time interval during which the reporting and spill processes actually occurred. Extrapolating to years following, or prior to, those for which the data are available can lead to obvious inaccuracies.

TABLE B-1. INDEPENDENT AND COMBINED RECORDING PROBABILITIES

λ	τ	P_1	P_2	P_3
$N_1/N_2 = 1.0$				
.0	.0	.000	.000	.000
.1	.0	.182	.182	.331
	.1	.000	.000	.000
.3	.0	.462	.462	.710
	.1	.308	.308	.521
	.2	.154	.154	.284
	.3	.000	.000	.000
.5	.0	.667	.667	.889
	.1	.533	.533	.782
	.2	.400	.400	.640
	.3	.267	.267	.462
	.4	.133	.133	.249
	.5	.000	.000	.000
.7	.0	.824	.824	.969
	.1	.706	.706	.913
	.2	.588	.588	.830
	.3	.471	.471	.720
	.4	.353	.353	.581
	.5	.235	.235	.415
	.6	.118	.118	.221
	.7	.000	.000	.000
.9	.0	.947	.947	.997
	.1	.842	.842	.975
	.2	.737	.737	.931
	.3	.632	.632	.864
	.4	.526	.526	.776
	.5	.421	.421	.665
	.6	.316	.316	.532
	.7	.211	.211	.377
	.8	.105	.105	.199
	.9	.000	.000	.000
$N_1/N_2 = 1.4$				
.0	.0	.000	.000	.000
.1	.0	.218	.156	.341
	.1	.000	.000	.000

TABLE B-1. (CONTINUED)

λ	τ	P_1	P_2	P_3
.3	.0	.554	.396	.730
	.1	.386	.256	.543
	.2	.205	.123	.303
	.3	.000	.000	.000
.5	.0	.800	.571	.914
	.1	.670	.443	.816
	.2	.533	.320	.683
	.3	.386	.204	.511
	.4	.218	.096	.293
	.5	.000	.000	.000
.7	.0	.988	.706	.997
	.1	.886	.586	.953
	.2	.784	.471	.886
	.3	.682	.359	.796
	.4	.578	.254	.685
	.5	.471	.157	.554
	.6	.353	.071	.399
	.7	.000	.000	.000
$\underline{N_1/N_2 = 1.8}$				
.0	.0	.000	.000	.000
.1	.0	.255	.141	.360
	.1	.000	.000	.000
.3	.0	.646	.359	.773
	.1	.473	.228	.593
	.2	.269	.108	.348
	.3	.000	.000	.000
.5	.0	.933	.519	.968
	.1	.820	.395	.891
	.2	.700	.280	.784
	.3	.568	.174	.643
	.4	.400	.080	.448
	.5	.000	.000	.000

TABLE B-1. (CONCLUDED)

LEGEND: Given that a spill has occurred,

P_1 = probability spill is recorded independently by source 1,

P_2 = probability spill is recorded independently by source 2,

P_3 = probability spill is recorded by either source,

τ = probability one source obtains spill record from the other source,

and

λ = fraction of all recorded spills that appear in both sources.

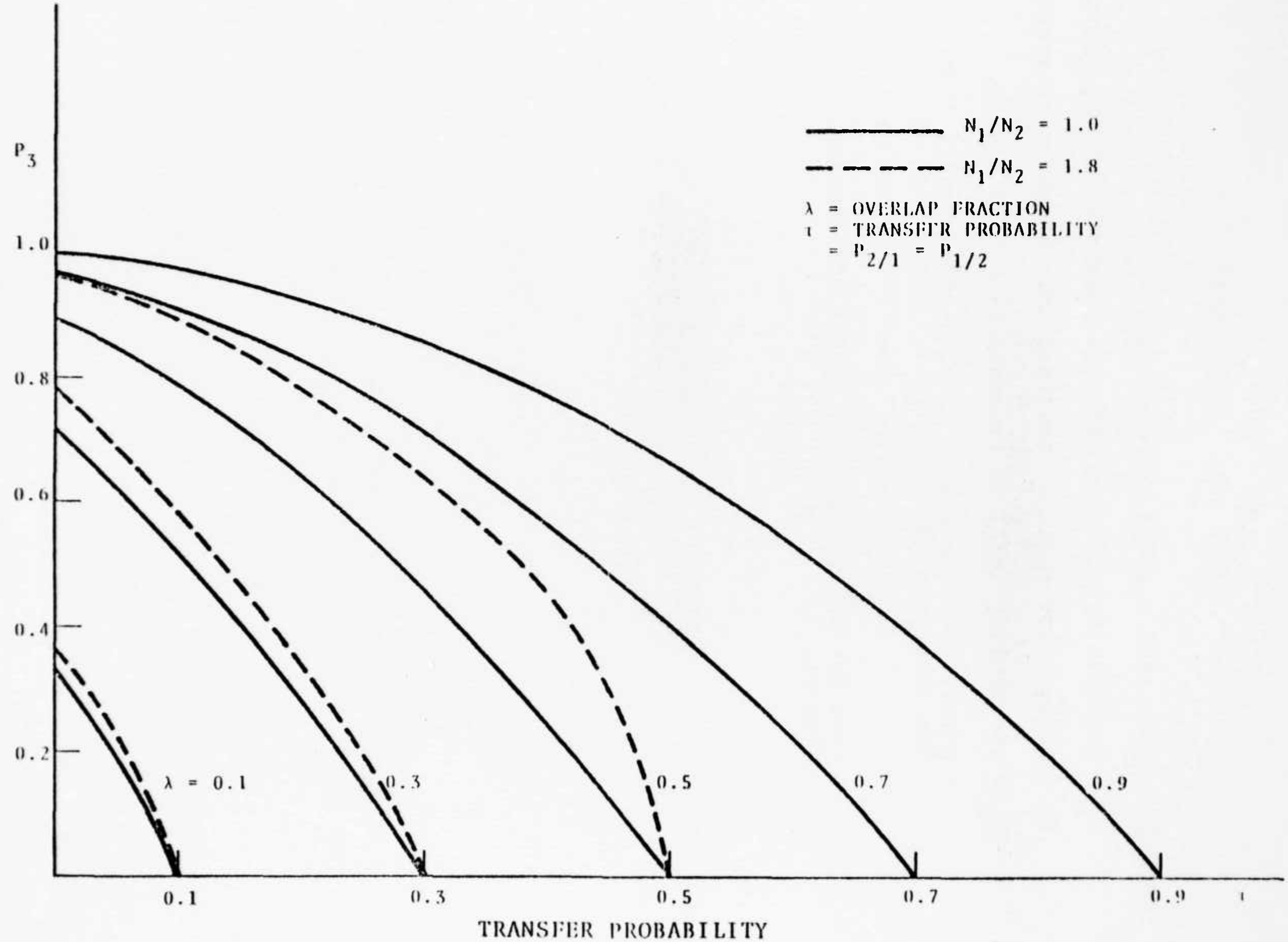

FIGURE B-2. PROBABILITY P3 OF A SPILL BEING RECORDED VS. TRANSFER PROBABILITY, ι

Second is the requirement that the sampling process, or in this case, the recording process, be representative. By that is meant that the two recording systems apply to the same population of spills, and that each has a fixed probability of recording any spill in that population. This is a more restrictive requirement. It is unrealized in practice to the extent that the spills (i.e., the spillers) seek out the recording system, rather than vice-versa. Reporting a spill to one of the systems, PIRS or NRC, is often considered adequate to insure that it will be reported to the other. Hence the probabilities P_1 and P_2 of independent reporting may not be descriptive, and the probability of two independent reports may not be P_1P_2. Further, certain types of spills, such as those from industrial plants and tank farms may be more likely to be reported through the NRC, and others, such as those from vessel accidents may be more likely to be reported to or by the US Coast Guard PIRS. These conditions would invalidate the assumption that the reported spills are representative samples of all spills, taken with probabilities P_1 and P_2 from the entire population of spills.

MATHEMATICAL NOTE

The formula (6) for N can be obtained by a more sophisticated method, given in Reference 18, pages 41-45. It is shown there that the probability that there will be exactly N_3 spills in common, given N_1, N_2, and N, is a hypergeometric distribution, and the value of N for which that probability is a maximum is given by (6).

A valuable result of the development given in Reference 18 is that it is not necessary to assume that <u>both</u> PIRS and NRC reports are made at random and independently; it is enough to assume that <u>either</u> the PIRS <u>or</u> the NRC reports are random, provided they are independent.

Another result of value in Reference 18 is the Normal approximation to the hypergeometric distribution of N_3. It is seen from p. 180 of that Reference that N_3 is Normally distributed with mean N_1N_2/N and variance $N_1N_2\ (N-N_1)\ (N-N_2)/N_3$. Thus, if one assumes a value for N, he may easily calculate the mean and variance of the observed overlap N_3.

APPENDIX C

MOVEMENT OF CRUDE, HEAVY, AND LIGHT OILS IN 1974-1977 FOR FOUR GEOGRAPHIC REGIONS OF THE UNITED STATES

EXTRACTED AND EXTRAPOLATED FROM - "Waterborne Commerce of the United States" for 1974-1976, excluding ports and waterways with less than 10,000 tons annual oil movement.

ACOE oil movement data are available at present for the years 1974, 1975, 1976 and 1977. Harbors and waterways having total oil movements of less than 10,000 tons/year were ignored. It is estimated that the the total amount of oil thus eliminated in any one region is less than 100,000 tons/year, or less than 0.2% of any regional oil flow.

The data were aggregated by oil type as follows (similar to Reference 9, p. 16):

Oil Type	Commodity Classification Numbers
Crude	1311
Heavy	2915, 2916, 2918
Light	2911, 2912, 2913, 2914, 2917.

The total oil movements tabulated for the four regions are given in the following listing by year and by port or waterway. In addition to the 10,000 tons/year exclusion, certain small rivers, canals and inland waterways were excluded. The major such exclusions, and other assumptions made in compiling the data for each region will now be discussed.

Greater New York: The greatest part of the traffic is contained in the Port of New York Consolidated Statement. This statement includes the Hudson River Channel up to 156th Street in Mahattan. The remainder of the Hudson River, through Troy, NY, may be obtained either from the statement for the Hudson River, Deepwater in Upper Bay, NY to Waterford, NY or from the statement for the Hudson River, Deepwater in Upper Bay, NY to Waterford, NY, or from the statement for the Hudson River, Mouth of Spuyten

Duyvil Creek to Waterford, NY. The former is slightly redundant with the Port of New York, Consolidated Report, while the latter leaves a slight gap in coverage from 136th Street to Spuyten Duyvil Creek. The redundancy was chosen.

The traffic through the Federal Lock at Troy was elimated since this oil is accounted for in the Hudson River Traffic.

Delaware Bay: Almost all traffic in this region is contained in the Consolidated Report of the Delaware River, Trenton, NJ to the Sea. This tabulation includes all non-local traffic of Trenton, Philadelphia, Camden, Marcus Hook, Wilmington and the main tributaries of the Delaware. The Schuylkill River movements are also included, except local. Traffic on the inland waterway between the Delaware River and Chesapeake Bay was excluded, as was traffic on Mantua Creek, NJ.

Louisiana Coast: The major difficulty in this region concerned the choice of data to represent the New Orleans and Baton Rouge areas. On one hand, one may employ the data for the Mississippi River, Baton Rouge to New Orleans and New Orleans to the Mouth of the Passes. This provides a complete statement of the River movements from above Baton Rouge to the Gulf of Mexico, with the through traffic called out separately. On the other hand, one may employ the data for the Port of Baton Rouge (Mile 168 through Mile 253) plus that for the Port of New Orleans (Mile 127 to Mouth of Passes). It was decided to employ the river data because the two separate Ports taken together still leave a section of the Mississippi River, from Mile 127 to Mile 168, unaccounted for. Examination of the data shows a significant amount of foreign crude oil passes through the New Orleans section of the Mississippi and lands in the Baton Rouge section of the Mississippi. This movement appears in the River data but not in the separate Ports data, presumably because of the gap in the Ports coverage.

Another difficulty in compiling the data in the Louisiana region is the method of handling oil movement on the Intracoastal Waterway and other inland waterways. It will be noted

that the spill data for the Louisiana region includes several spills on the Intracoastal Waterway and one in Bayou Black. The inland waterways in the Louisiana region carry about 30 million tons of oil per year, of which about half is through movement. Although oil movement on these waterways is primarily barge traffic and hence not likely to result in massive spills, it nevertheless is a significant contributor to the spill rate and for that reason was included in the oil movement total for Louisiana.

North Texas Coast: Almost all oil movements in this region were included in this Appendix, the only exclusions being less than 100,000 tons annually. The movement on the Lake Charles Deepwater channel was assigned entirely to the Louisiana Coast region. Similarly, all of the movements on the Galveston-Corpus Christi section of the Intracoastal Waterway were included in the North Texas region.

General: Some general observations may be made on the use of ACOE data in calculating oil spill rates.

First, it appears that the selection of the appropriate types of oil movement is not an easy task. We have, in this Appendix, taken the aggregate of imports, exports, coastwise receipts and shipments, internal receipts and shipments, and local receipts and shipments. We also have included through traffic on the grounds that it is about as likely to produce spills as traffic in the other categories.

Second, it may be observed that consistency does not necessarily avoid biasing of the resultant spill rates. For example, inclusion of inland waterway traffic has a greater impact on the Louisiana Coast spill rate than on the spill rate of any other region, because of the large amount of waterway movement in Louisiana. The same may be said of the inclusion of through traffic, which also is heavy in the Louisiana Coast region.

ACOE OIL MOVEMENT DATA FOR FOUR US COASTAL AREAS
1974 THROUGH 1977
THOUSANDS OF SHORT TONS

	OCEANGOING----- FOREIGN AND COASTAL	THROUGH	--- INTERNAL------ RECEIPTS AND SHIPMNTS	THROUGH
NEW LONDON HARBOR, CT				
1974				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	50.8	0.0	0.9	0.0
HEAVY	1424.5	0.0	601.0	0.0
1975				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	258.5	0.0	0.0	0.0
HEAVY	2683.2	0.0	385.6	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	265.5	0.0	0.4	0.0
HEAVY	2560.9	0.0	206.6	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	261.0	0.0	1.7	0.0
HEAVY	1836.4	0.0	228.2	0.0
THAMES RIVER, CT				
1974				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	236.8	0.0	0.6	0.0
HEAVY	253.4	0.0	599.2	0.0
1975				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	250.2	0.0	0.0	0.0
HEAVY	133.6	0.0	385.6	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	250.1	0.0	0.0	0.0
HEAVY	104.5	0.0	206.6	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	263.0	0.0	1.7	0.0
HEAVY	48.1	0.0	228.2	0.0

CONNECTICUT RIVER BELOW HARTFORD, CT

1974				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1279.8	0.0	3.6	0.0
HEAVY	1752.0	0.0	0.0	0.0
1975				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1116.4	0.0	3.5	0.0
HEAVY	1436.8	0.0	0.0	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1076.8	0.0	1.7	0.0
HEAVY	1136.3	0.0	0.0	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1064.9	0.0	0.0	0.0
HEAVY	1070.1	0.0	23.0	0.0

NEW HAVEN HARBOR, CT

1974				
CRUDE	42.3	0.0	0.0	0.0
LIGHT	7270.3	0.0	283.9	0.0
HEAVY	3325.1	0.0	27.1	0.0
1975				
CRUDE	132.6	0.0	0.0	0.0
LIGHT	6940.6	0.0	291.4	0.0
HEAVY	3034.7	0.0	209.7	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	9425.3	0.0	134.1	0.0
HEAVY	2886.2	0.0	81.6	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	7201.3	0.0	115.1	0.0
HEAVY	2824.3	0.0	36.8	0.0

BRIDGEPORT HARBOR, CT

1974				
CRUDE	11.7	0.0	0.0	0.0
LIGHT	1376.0	0.0	72.8	0.0
HEAVY	1363.2	0.0	0.0	0.0
1975				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1341.1	0.0	3.9	0.0
HEAVY	1151.4	0.0	29.2	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1574.4	0.0	0.0	0.0
HEAVY	1312.8	0.0	11.3	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1611.7	0.0	0.0	0.0
HEAVY	1247.9	0.0	3.1	0.0

NORWALK HARBOR, CT					
1974					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	178.0	0.0	0.0	0.0	
HEAVY	555.1	0.0	0.0	0.0	
1975					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	201.5	0.0	0.0	0.0	
HEAVY	543.5	0.0	0.0	0.0	
1976					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	232.2	0.0	0.0	0.0	
HEAVY	483.7	0.0	0.0	0.0	
1977					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	207.0	0.0	0.0	0.0	
HEAVY	573.1	0.0	0.0	0.0	
STAMFORD HARBOR, CT					
1974					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	485.5	0.0	0.0	0.0	
HEAVY	55.2	0.0	0.0	0.0	
1975					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	472.1	0.0	0.0	0.0	
HEAVY	35.6	0.0	0.0	0.0	
1976					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	456.1	0.0	0.0	0.0	
HEAVY	62.3	0.0	0.0	0.0	
1977					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	458.8	0.0	0.0	0.0	
HEAVY	78.9	0.0	0.0	0.0	
HEMPSTEAD HARBOR, NY					
1974					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	684.0	0.0	0.0	0.0	
HEAVY	223.7	0.0	0.0	0.0	
1975					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	714.4	0.0	0.0	0.0	
HEAVY	135.0	0.0	0.0	0.0	
1976					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	578.6	0.0	0.0	0.0	
HEAVY	288.7	0.0	0.0	0.0	
1977					
CRUDE	0.0	0.0	0.0	0.0	
LIGHT	464.1	0.0	0.0	0.0	
HEAVY	197.6	0.0	0.0	0.0	

PORT JEFFERSON HARBOR, NY				
1974				
CRUDE	6.5	0.0	0.0	0.0
LIGHT	3114.7	0.0	7.7	0.0
HEAVY	641.0	0.0	0.0	0.0
1975				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	3150.9	0.0	0.0	0.0
HEAVY	650.9	0.0	0.0	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	3371.9	0.0	0.0	0.0
HEAVY	609.5	0.0	0.0	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	3448.9	0.0	0.0	0.0
HEAVY	654.0	0.0	0.0	0.0
PORT CHESTER HARBOR, NY				
1974				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	0.0	0.0	157.6	0.0
HEAVY	0.0	0.0	0.0	0.0
1975				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	0.0	0.0	169.0	0.0
HEAVY	0.0	0.0	4.5	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	0.0	0.0	176.2	0.0
HEAVY	0.0	0.0	7.9	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	0.0	0.0	198.0	0.0
HEAVY	0.0	0.0	4.9	0.0
OYSTER BAY HARBOR				
1974				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	525.9	0.0	0.0	0.0
HEAVY	0.0	0.0	0.0	0.0
1975				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	468.5	0.0	0.0	0.0
HEAVY	0.0	0.0	0.0	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	360.0	0.0	0.0	0.0
HEAVY	136.8	0.0	0.0	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	374.9	0.0	0.0	0.0
HEAVY	12.9	0.0	0.0	0.0

TOTALS, LONG ISLAND SOUND

1974				
CRUDE	69.5	0.0	0.0	0.0
LIGHT	15201.8	0.0	519.4	0.0
HEAVY	9593.2	0.0	1227.3	0.0
1975				
CRUDE	132.6	0.0	0.0	0.0
LIGHT	14914.2	0.0	467.8	0.0
HEAVY	9805.7	0.0	1014.6	0.0
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	17590.9	0.0	312.4	0.0
HEAVY	9581.7	0.0	514.0	0.0
1977				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	15355.6	0.0	316.5	0.0
HEAVY	8543.3	0.0	529.1	0.0

CONSOLIDATED STATEMENT OF THE PORT OF NEW YORK

1974				
CRUDE	20005.3	0.0	1146.8	0.0
LIGHT	35387.7	0.0	26922.8	0.0
HEAVY	35194.5	0.0	20176.4	0.0
1975				
CRUDE	19886.4	0.0	1026.6	0.0
LIGHT	35723.9	0.0	23955.1	0.0
HEAVY	29616.3	0.0	19201.2	0.0
1976				
CRUDE	22833.5	0.0	2071.7	0.0
LIGHT	34200.2	0.0	24066.8	0.0
HEAVY	33951.3	0.0	20419.0	0.0
1977				
CRUDE	24266.6	0.0	2675.0	0.0
LIGHT	39270.0	0.0	24836.0	0.0
HEAVY	35633.4	0.0	19238.4	0.0

HUDSON RIVER, DEEPWATER IN UPPER BAY TO WATERFORD, NY

1974				
CRUDE	74.9	0.0	0.0	0.0
LIGHT	1490.9	0.0	8008.7	684.8
HEAVY	2671.2	92.5	5353.7	197.7
1975				

CRUDE	0.0	0.0	0.0	0.0
LIGHT	1504.5	0.0	7009.7	396.0
HEAVY	3730.8	22.0	4925.7	133.1
1976				
CRUDE	0.0	0.0	0.0	0.0
LIGHT	1329.2	0.0	7834.3	475.7
HEAVY	3592.4	6.0	4672.1	104.6
1977				
CRUDE	1.0	0.0	0.0	0.0
LIGHT	1731.4	0.0	7504.2	517.3
HEAVY	3308.5	0.0	4364.6	125.8

DELAWARE RIVER, TRENTON NJ TO THE SEA CONSOLIDATED REPORT

1974				
CRUDE	47104.6	1292.5	9068.5	0.0
LIGHT	14146.1	3541.2	8047.0	1088.6
HEAVY	10597.7	2914.4	7254.8	484.7
1975				
CRUDE	47167.5	674.5	9992.8	0.0
LIGHT	12981.1	2505.6	6874.6	510.7
HEAVY	6909.0	2430.1	6437.3	304.4
1976				
CRUDE	52262.6	323.9	9846.7	0.0
LIGHT	11912.8	3198.1	6117.3	355.4
HEAVY	9247.5	2501.6	10163.3	142.6
1977				
CRUDE	54450.7	444.0	11044.3	0.0
LIGHT	12137.0	3992.7	1698.6	274.5
HEAVY	8941.0	2952.5	8810.2	239.9

GICWW, MOBILE BAY TO NEW ORLEANS, LA

1974				
CRUDE	0.0	0.0	4.1	1424.2
LIGHT	0.0	77.9	272.3	4123.7
HEAVY	0.0	3.1	167.7	2917.4
1975				
CRUDE	0.0	0.0	6.4	2653.8
LIGHT	0.0	0.0	252.0	4161.6
HEAVY	0.0	0.0	148.0	2785.7
1976				
CRUDE	0.0	0.0	3.3	3485.2
LIGHT	0.0	39.7	125.7	3820.4
HEAVY	0.0	67.4	276.8	3379.7
1977				
CRUDE	0.0	0.0	0.0	3466.0
LIGHT	0.0	0.0	20.1	4611.3
HEAVY	61.9	76.7	72.4	4113.0

GICWW, MISSISSIPPI RIVER TO SABINE RIVER				
1974				
CRUDE	0.0	0.0	10731.2	8259.8
LIGHT	0.0	0.0	717.7	5610.5
HEAVY	0.0	0.0	498.3	8433.2
1975				
CRUDE	0.0	0.0	9672.8	7502.7
LIGHT	0.0	0.0	1069.5	5972.2
HEAVY	0.0	3.2	291.5	7523.5
1976				
CRUDE	0.0	0.0	9448.3	7257.1
LIGHT	0.0	4.9	615.9	6899.8
HEAVY	0.0	29.4	377.9	8745.5
1977				
CRUDE	0.0	0.0	8885.5	7309.7
LIGHT	0.0	0.0	752.7	8934.5
HEAVY	0.0	6.1	470.7	10600.2
GICWW, MORGAN CITY - PORT ALLEN ROUTE				
1974				
CRUDE	0.0	0.0	769.6	267.9
LIGHT	0.0	0.0	210.7	2357.6
HEAVY	0.0	0.0	3.7	3924.3
1975				
CRUDE	0.0	0.0	685.7	514.9
LIGHT	0.0	0.0	248.8	2750.7
HEAVY	0.0	0.0	0.0	3784.4
1976				
CRUDE	0.0	0.0	816.2	744.6
LIGHT	0.0	0.0	227.2	2975.0
HEAVY	0.0	0.0	0.0	3889.2
1977				
CRUDE	0.0	0.0	560.9	347.0
LIGHT	0.0	0.0	287.4	3354.0
HEAVY	0.0	0.0	0.0	4219.5
HOUMA NAVIGATION CANAL, LA				
1974				
CRUDE	0.0	0.0	0.0	1369.2
LIGHT	0.0	0.0	2.2	67.8
HEAVY	0.0	0.0	5.6	0.0
1975				
CRUDE	0.0	0.0	0.0	1138.4
LIGHT	0.0	0.0	0.0	117.8
HEAVY	0.0	0.0	0.0	0.0
1976				
CRUDE	0.0	0.0	0.0	1232.3
LIGHT	0.0	0.0	0.0	47.7
HEAVY	0.0	0.0	0.0	0.0
1977				
CRUDE	0.0	0.0	0.0	1228.2
LIGHT	0.0	0.0	0.0	69.3
HEAVY	0.0	0.0	0.0	0.0

MERMANTEAU RIVER, LA				
1974				
CRUDE	0.0	0.0	1713.8	15.0
LIGHT	0.0	0.0	86.8	0.0
HEAVY	0.0	0.0	2.8	0.0
1975				
CRUDE	0.0	0.0	1254.5	0.0
LIGHT	0.0	0.0	1.5	0.0
HEAVY	0.0	0.0	0.2	0.0
1976				
CRUDE	0.0	0.0	1485.5	13.9
LIGHT	0.0	0.0	67.8	0.0
HEAVY	0.0	0.0	0.0	0.0
1977				
CRUDE	0.0	0.0	1515.0	32.4
LIGHT	0.0	0.0	0.0	0.0
HEAVY	0.0	0.0	0.7	0.0
MISSISSIPPI RIVER, NEW ORLEANS TO MOUTH OF PASSES				
1974				
CRUDE	7796.9	14833.3	12744.6	3008.9
LIGHT	1007.7	7854.2	4411.7	2771.3
HEAVY	1740.7	2330.6	5258.8	3343.6
1975				
CRUDE	6840.8	26568.2	13797.6	4975.0
LIGHT	1886.5	8089.7	3895.3	2682.6
HEAVY	1418.5	3351.1	4437.9	3256.4
1976				
CRUDE	6345.7	43987.3	12933.5	4518.9
LIGHT	1140.6	7783.9	3720.4	1663.0
HEAVY	772.6	3832.0	4819.4	3124.5
1977				
CRUDE	13548.8	65424.4	10670.4	5054.4
LIGHT	944.5	8761.8	3643.1	4572.7
HEAVY	748.6	4886.3	6463.1	5345.1
MISSISSIPPI RIVER, BATON ROUGE TO NEW ORLEANS				
1974				
CRUDE	14833.4	0.0	8110.0	1964.3
LIGHT	7854.2	0.0	8523.4	4011.0
HEAVY	2328.4	0.0	7089.0	5177.2
1975				
CRUDE	26568.3	0.0	8781.7	3044.0
LIGHT	8089.8	0.0	9066.9	3848.8
HEAVY	3336.2	8.6	6495.7	4791.3
1976				
CRUDE	43987.3	0.0	8263.3	3049.9
LIGHT	7779.4	0.0	11077.6	4030.0
HEAVY	3801.6	0.0	8279.9	4086.4
1977				
CRUDE	65424.4	0.0	7183.1	1734.5
LIGHT	8761.7	0.0	10412.0	3925.0
HEAVY	4863.9	0.0	9635.8	3956.7

CALCASIEU RIVER AND PASS, LA				
1974				
CRUDE	2274.7	0.0	5583.7	0.0
LIGHT	1527.9	0.0	902.0	0.0
HEAVY	309.6	0.0	1021.4	0.0
1975				
CRUDE	4630.6	0.0	4760.4	0.0
LIGHT	1436.8	0.0	820.7	0.0
HEAVY	245.8	0.0	861.9	0.0
1976				
CRUDE	5738.0	0.0	4204.2	0.0
LIGHT	1914.8	0.0	1170.9	0.0
HEAVY	376.7	0.0	1290.3	0.0
1977				
CRUDE	8068.8	0.0	4674.1	0.0
LIGHT	3359.2	0.0	1929.8	0.0
HEAVY	195.7	0.0	1796.1	0.0
ATCHAFALAYA RIVER, LA				
1974				
CRUDE	0.0	0.0	224.0	959.3
LIGHT	0.0	0.0	166.9	529.8
HEAVY	0.0	0.0	149.7	1147.1
1975				
CRUDE	0.0	0.0	274.2	729.9
LIGHT	0.0	0.0	277.0	323.5
HEAVY	0.0	0.0	144.1	594.9
1976				
CRUDE	0.0	0.0	375.9	738.4
LIGHT	0.0	0.0	327.0	893.8
HEAVY	0.0	0.0	150.9	984.9
1977				
CRUDE	0.0	0.0	301.9	479.0
LIGHT	0.0	0.0	465.6	740.7
HEAVY	0.0	0.0	195.8	947.8
TOTALS, LOUISIANA COAST				
1974				
CRUDE	24905.0	14833.3	39881.0	17268.6
LIGHT	10389.8	7854.2	15293.7	19470.9
HEAVY	4378.7	2333.7	14197.0	24942.8
1975				
CRUDE	38039.7	26568.2	38133.3	20558.7
LIGHT	11413.1	8089.7	15631.7	19857.2
HEAVY	5000.5	3362.9	12379.3	22736.2
1976				
CRUDE	61071.0	43987.3	37530.2	21030.3
LIGHT	56071.0	43987.3	37530.2	21040.3
HEAVY	4950.9	3928.8	15195.2	24210.3
1977				
CRUDE	87042.0	65424.4	33790.9	16185.2
LIGHT	13065.4	8761.8	17490.6	21596.2
HEAVY	5808.2	4892.4	18561.5	25069.1

SABINE-NECHES WATERWAY, TX				
1974				
CRUDE	19462.1	0.0	3991.6	5197.6
LIGHT	12587.1	0.0	4497.3	2646.9
HEAVY	4705.3	0.0	3254.6	5374.1
1975				
CRUDE	17938.3	0.0	4365.2	4191.1
LIGHT	12008.3	0.0	4782.3	2789.3
HEAVY	3879.6	0.0	3536.5	4000.4
1976				
CRUDE	32213.1	0.0	4832.6	4825.0
LIGHT	13115.6	0.0	3682.1	3364.7
HEAVY	5336.2	0.0	3980.9	5295.4
1977				
CRUDE	38648.7	0.0	5559.2	4368.6
LIGHT	10980.7	0.0	3372.1	4719.4
HEAVY	5243.5	0.0	3938.5	6666.1
HOUSTON SHIP CANAL, TX				
1974				
CRUDE	14874.7	0.0	3934.2	0.0
LIGHT	15888.4	0.0	3863.5	0.0
HEAVY	3308.3	0.0	5892.1	0.0
1975				
CRUDE	16012.3	0.0	2996.4	0.0
LIGHT	14535.5	0.0	2864.3	0.0
HEAVY	2997.6	0.0	5111.7	0.0
1976				
CRUDE	22039.0	0.0	3466.6	0.0
LIGHT	14239.9	0.0	3449.7	0.0
HEAVY	2417.3	0.0	5961.4	0.0
1977				
CRUDE	28191.7	0.0	3584.2	0.0
LIGHT	14437.8	0.0	7220.7	0.0
HEAVY	4935.2	0.0	8778.2	0.0
TEXAS CITY CHANNEL, TX				
1974				
CRUDE	7696.6	0.0	3576.2	0.0
LIGHT	3296.9	0.0	2664.9	0.0
HEAVY	425.4	0.0	787.6	0.0
1975				
CRUDE	5618.5	0.0	3466.1	0.0
LIGHT	5494.8	0.0	2332.0	0.0
HEAVY	574.2	0.0	745.6	0.0
1976				
CRUDE	9598.6	0.0	2690.0	0.0
LIGHT	4556.6	0.0	3002.6	0.0
HEAVY	859.4	0.0	1012.2	0.0
1977				
CRUDE	12887.3	0.0	3275.2	0.0
LIGHT	4282.6	0.0	4041.6	0.0
HEAVY	1179.3	0.0	1554.7	0.0

GALVESTON CHANNEL, TX

1974				
CRUDE	203.4	0.0	6.0	0.0
LIGHT	0.0	0.0	47.0	0.0
HEAVY	0.0	0.0	102.1	0.0
1975				
CRUDE	233.3	0.0	16.5	0.0
LIGHT	0.0	0.0	52.4	0.0
HEAVY	0.0	0.0	74.8	0.0
1976				
CRUDE	118.7	0.0	0.0	0.0
LIGHT	0.0	0.0	74.5	0.0
HEAVY	2.3	0.0	122.8	0.0
1977				
CRUDE	493.9	0.0	15.7	0.0
LIGHT	70.8	0.0	42.6	0.0
HEAVY	7.8	0.0	173.3	0.0

FREEPORT HARBOR, TX

1974				
CRUDE	2060.1	0.0	1005.2	0.0
LIGHT	536.2	0.0	454.6	0.0
HEAVY	0.0	0.0	170.3	0.0
1975				
CRUDE	3228.4	0.0	622.3	0.0
LIGHT	484.3	0.0	124.7	0.0
HEAVY	0.0	0.0	108.8	0.0
1976				
CRUDE	4458.5	0.0	477.2	0.0
LIGHT	545.6	0.0	107.4	0.0
HEAVY	0.0	0.0	195.8	0.0
1977				
CRUDE	9980.6	0.0	313.2	0.0
LIGHT	528.1	0.0	128.4	0.0
HEAVY	0.0	0.0	313.9	0.0

MATAGORDA SHIP CHANNEL, TX

1974				
CRUDE	0.0	0.0	167.9	0.0
LIGHT	0.0	0.0	1.5	0.0
HEAVY	61.1	0.0	8.5	0.0
1975				
CRUDE	0.0	0.0	190.5	0.0
LIGHT	0.0	0.0	4.6	0.0
HEAVY	44.9	0.0	22.1	0.0
1976				
CRUDE	0.0	0.0	178.3	0.0
LIGHT	0.0	0.0	13.4	0.0
HEAVY	27.8	0.0	16.9	0.0

1977				
CRUDE	0.0	0.0	139.6	0.0
LIGHT	0.0	0.0	5.1	0.0
HEAVY	0.0	0.0	17.5	0.0
GICWW, SABINE RIVER TO GALVESTON, TX				
1974				
CRUDE	0.0	0.0	811.4	8785.4
LIGHT	0.0	0.0	1909.0	5093.4
HEAVY	0.0	0.0	1745.5	6827.6
1975				
CRUDE	0.0	0.0	1184.8	7575.9
LIGHT	0.0	0.0	2672.6	4839.8
HEAVY	0.0	3.2	1688.8	5805.2
1976				
CRUDE	0.0	0.0	1010.5	8783.7
LIGHT	4.9	0.0	1772.7	5665.1
HEAVY	4.0	25.4	1741.7	7188.8
1977				
CRUDE	0.0	0.0	1446.1	8561.0
LIGHT	0.0	0.0	1837.1	7476.8
HEAVY	0.0	0.0	1898.5	8693.1
GICWW, GALVESTON TO CORPUS CHRISTI, TX				
1974				
CRUDE	0.0	0.0	2102.9	2130.4
LIGHT	0.0	0.0	271.2	2682.8
HEAVY	0.0	0.0	355.8	1349.1
1975				
CRUDE	0.0	0.0	2414.8	1845.1
LIGHT	0.0	0.0	621.3	1385.7
HEAVY	0.0	0.0	208.6	964.8
1976				
CRUDE	0.0	0.0	1469.3	2438.0
LIGHT	0.0	0.0	154.4	1352.2
HEAVY	0.0	0.0	254.0	1290.2
1977				
CRUDE	0.0	0.0	1948.7	2723.8
LIGHT	0.0	0.0	214.0	1855.7
HEAVY	0.0	0.0	268.3	1655.2

TOTALS, NORTH TEXAS COAST

1974				
CRUDE	19834.8	0.0	11603.8	10915.8
LIGHT	19721.5	0.0	19211.7	7776.2
HEAVY	3369.4	0.0	9061.9	8176.7
1975				
CRUDE	43030.8	0.0	15256.6	13612.1
LIGHT	32522.9	0.0	13454.2	9014.8
HEAVY	7496.3	3.2	11496.9	10770.4
1976				
CRUDE	68427.9	0.0	14124.5	16046.7
LIGHT	32462.6	0.0	12256.8	10382.0
HEAVY	8647.0	25.4	13285.7	13774.4
1977				
CRUDE	90292.2	0.0	16281.9	15653.4
LIGHT	30300.0	0.0	16861.6	14051.9
HEAVY	11365.8	0.0	16942.9	17014.4

APPENDIX D

TRIPS OF TANKERS, TANK BARGES, AND ALL VESSELS IN 1974-1977 FOR FOUR GEOGRAPHIC REGIONS OF THE UNITED STATES

EXTRACTED AND EXTRAPOLATED FROM - "Waterborne Commerce of the United States" (Army Corps of Engineers) for 1974-1976, excluding ports and waterways with less than 10,000 tons annual oil movement.

The vessel trip data here tabulated were extracted from the ACOE volumes for the same waterways as were the tonnage data of Appendix C, with few exceptions. (1) The trip data do not include a consolidated statement of the Port of New York, analogous to that found in the tonnage data. Therefore, the trip data for the separate waterways that constitute the Port of New York as given in Table D-1 were summed to arrive at an equivalent consolidated statement of the Port of New York. (2) The Waterways given in Table D-2 were summed and are shown on the listing as Louisiana Inland Waterways. The list of Table D-2 includes six waterways (items 3 through 8) that are not included in the tonnage movement data of Appendix C, but these waterways comprise a relatively small fraction of all vessel trips in Louisiana. Hence the Louisiana Coast vessel trip data, for all practical purposes, covers the same waterways as the tonnage data.

TABLE D-1. WATERWAYS IN THE NEW YORK CONSOLIDATED STATEMENT, ACOE DATA

The following waterways make up the Port of New York in the ACOE consolidated statement:

Eastchester Creek, NY
Bronx River, NY
Westchester Creek, NY
Manhasset Bay, NY
Flushing Bay and Creek, NY
Harlem River, NY
Hudson River, NY (Lower section)
Hudson River Channel, NY and NJ
East River, NY
Newtown Creek, NY
Buttermilk Channel, NY
Bay Ridge and Red Hook Channels, NY
Gowanus Creek Channel, NY
Gowanus Canal, NY
Gravesend Bay, NY
Coney Island Channel, NY
East Rockaway Inlet, NY
Jamaica Bay, NY
Raritan River, NJ
Upper Bay, New York Harbor, NY and NJ
Newark Bay, NJ
Hackensack River, NJ
Passaic River, NJ
New York and New Jersey Channels, NY and NJ
Raritan River to Arthur Kill Cutoff Channel, NJ
New York Harbor, NY, Lower Entrance Channels

TABLE D-2. LOUISIANA INLAND WATERWAYS

1. Gulf Intracoastal Waterway, Mobile AL to New Orleans, LA
2. Gulf Intracoastal Waterway, Mississippi River to Sabine, TX
3. Inner Harbor Navigation Canal, New Orleans, LA
4. Mississippi River - Gulf Outlet, LA
5. Waterway from Empire, LA to Gulf of Mexico
6. Barataria Bay Waterway, LA
7. Bayou Lafourche and Lafourche-Jump Waterway, LA
8. Bayou Little Caillou, LA
9. Huma Navigation Canal, LA
10. Gulf Intracoastal Waterway, Morgan City - Port Allen Route
11. Mermantau River and Bayous Nezpique and DesCannes, LA

TRIPS OF TANKERS, BARGES AND ALL VESSELS
FOR FOUR US COASTAL AREAS
1974 THROUGH 1977

	1974	1975	1976	1977
NEW LONDON HARBOR AND THAMES RIVER, CT				
TANKERS	631	508	505	422
BARGES	1474	1251	959	713
ALL TYPES	20184	10792	14278	9179
CONNECTICUT RIVER BELOW HARTFORD, CT				
TANKERS	516	430	562	549
BARGES	1374	1172	917	697
ALL TYPES	67706	68143	66683	66488
NEW HAVEN HARBOR, CT				
TANKERS	1542	1308	1376	1243
BARGES	2014	2308	2007	2103
ALL TYPES	9283	8595	9010	8690
BRIDGEPORT HARBOR, CT				
TANKERS	209	223	192	191
BARGES	602	598	647	661
ALL TYPES	3746	3825	3876	3946
NORWALK HARBOR, CT				
TANKERS	90	80	77	69
BARGES	291	304	320	334
ALL TYPES	2340	2720	2768	3037
STAMFORD HARBOR, CT				
TANKERS	305	296	292	285
BARGES	281	244	224	193
ALL TYPES	2284	1999	1611	1292
OYSTER BAY, NY				
TANKERS	364	339	248	139
BARGES	214	172	184	189
ALL TYPES	2233	2119	2187	1686
PORT CHESTER, NY				
TANKERS	239	235	241	325
BARGES	37	70	62	43
ALL TYPES	879	921	792	840
PORT JEFFERSON, NY				
TANKERS	712	561	504	384
BARGES	911	1086	560	501
ALL TYPES	8970	9064	8715	8661
HEMPSTEAD HARBOR, NY				
TANKERS	505	435	199	74
BARGES	504	485	577	595
ALL TYPES	9774	7111	4284	1563
TOTALS, LONG ISLAND SOUND				
TANKERS	5113	4415	4196	3681
BARGES	7702	7760	6457	6029
ALL TYPES	127399	115289	114204	105382

PORT OF NEW YORK, TABLE D-1.				
TANKERS	74187	63806	59994	51798
BARGES	93590	85666	84286	78498
ALL TYPES	793452	675907	616054	518187
HUDSON RIVER, DEEPWATER IN UPPER BAY TO WATERFORD, NY				
TANKERS	2333	1904	1811	1494
BARGES	8534	7370	7738	7085
ALL TYPES	110884	92953	78930	62302
DELAWARE RIVER, TRENTON NJ TO THE SEA, CONSOLIDATED REPORT				
TANKERS	5144	4501	4504	4076
BARGES	16483	13528	14262	12537
ALL TYPES	118807	119612	94907	87209
LOUISIANA INLAND WATERWAYS, TABLE D-2.				
TANKERS	35	40	12	6
BARGES	75306	80464	78623	81448
ALL TYPES	337633	382947	407545	445954
MISSISSIPPI RIVER, NEW ORLEANS TO MOUTH OF PASSES				
TANKERS	4275	4702	4769	5076
BARGES	38717	41969	38218	39136
ALL TYPES	167652	173744	172361	175961
MISSISSIPPI RIVER, BATON ROUGE TO NEW ORLEANS				
TANKERS	2558	3110	3425	3898
BARGES	44381	48503	47049	49312
ALL VESSELS	152963	161751	175120	185435
CALCASIED RIVER AND PASS, LA				
TANKERS	605	584	693	715
BARGES	8746	8290	8506	8274
ALL VESSELS	30869	34128	38347	41926
ATCHAFALAYA RIVER, LA				
TANKERS	0	0	0	0
BARGES	4367	3405	5015	4910
ALL VESSELS	43508	47358	45391	47302
TOTALS, LOUISIANA COAST				
TANKERS	7473	8436	8899	9695
BARGES	171517	182631	177411	183080
ALL TYPES	564973	799928	838764	896578

SABINE-NECHES WATERWAY, TX				
TANKERS	3003	2691	3321	3323
BARGES	29639	28321	30520	30374
ALL VESSELS	70550	65592	71898	70695
HOUSTON SHIP CHANNEL, TX				
TANKERS	3169	2984	3149	3081
BARGES	21439	19299	21232	20450
ALL VESSELS	66299	61545	69940	69569
TEXAS CITY CHANNEL, TX				
TANKERS	1017	1276	1321	1508
BARGES	11157	9792	10785	10205
ALL VESSELS	16753	14780	17054	16497
GALVESTON CHANNEL, TX				
TANKERS	242	225	203	184
BARGES	745	605	527	408
ALL VESSELS	5952	6464	8455	9460
FREEPORT HARBOR, TX				
TANKERS	721	575	704	650
BARGES	3562	2700	2911	2895
ALL VESSELS	8765	6767	7583	7360
MATAGORDA SHIP CHANNEL, TX				
TANKERS	9	6	15	16
BARGES	659	571	586	532
ALL VESSELS	2186	2201	2136	2124
GICWW, SABINE RIVER TO GALVESTON, TX				
TANKERS	102	99	110	112
BARGES	29212	28007	30039	29913
ALL VESSELS	59086	55687	62306	62246
GICWW, GALVESTON TO CORPUS CHRISTI, TX				
TANKERS	10	12	18	22
BARGES	14092	13010	12594	11734
ALL VESSELS	46142	45610	52254	54114
TOTALS, NORTH TEXAS COAST				
TANKERS	8273	7868	8841	8896
BARGES	110505	102305	109194	106511
ALL VESSELS	275733	258646	291626	292065

APPENDIX E
A BRIEF DISCUSSION OF THREE TECHNIQUES TO ESTIMATE OIL SPILL RATES FROM HISTORIC DATA

The fundamental assumption made in the spill rate calculation to follow is that spills are a Poisson process on the exposure variable. This means that (Reference 14, p 14):

(a) The probability of at least one spill occurring during exposure Δt approaches the value $\lambda(\Delta t)$ as Δt approaches 0, where $\lambda>0$.

(b) The probability of two or more spills occurring during exposure Δt approaches 0 as Δt approaches 0.

It might be noted from (b) that collisions of oil-carrying vessels are not a Poisson process if they result in multiple spills; it is necessary to count the spills resulting from a collision as a single spill if they are to be considered part of a Poisson process.

Given the assumption of a Poisson process, the question arises: How does one estimate the spill rate parameter λ given several years of historic spill and exposure data? Three approaches will be discussed very briefly, in order of decreasing complexity.

1) Maximum Likelihood Estimate

The idea behind this approach is to choose λ so as to maximize the probability of the actually observed spills. By the Poisson assumption, the probability of n_i spills in exposure t_i is P_i, and the probability of the set of observations is P:

$$P_i = (\lambda t_i)^{n_i} \frac{e^{-\lambda t_i}}{n_i!} \quad , \quad P = \prod_i P_i \qquad \text{(E-1)}$$

This rate λ may be selected so as to maximize P for, say, i = 1974, 1975, 1976, 1977. The result is

$$\sum_{i=1}^{i}(\lambda t_i - n_i) = 0 \quad , \tag{E-2}$$

which will be seen to be identical to that of the next approach to be discussed.

2) <u>Posterior/Prior Analysis</u>

This approach is described in Reference 4. The authors start out with the assumption that, prior to the incorporation of the n_i, t_i data, the spill rate λ has a Gamma distribution

$$f(\lambda) = e^{-\lambda\omega}(\lambda\omega)^{\rho-1}\omega/(\rho-1)! \tag{E-3}$$

with both parameters ρ and ω approaching zero. This essentially distributes λ uniformly everywhere on the positive axis, corresponding to almost complete ignorance.

When the observational data n_i, t_i are available, the new (posterior) distribution of λ may be calculated:

$$f(\lambda/n_i,t_i) = f(n_i/\lambda,t_i)\ f(\lambda)/f(n_i/t_i)$$

$$= f(n_i/\lambda,t_i)\ f(\lambda)/\int f(n_i/\lambda,t_i)\ f(\lambda)d\lambda.$$

The distribution $f(n_i/\lambda,t_i)$ is now assumed to be Poisson, and the prior distribution $f(\lambda)$ is the Gamma assumed above. When these two functions are put into the right side and simplified the result is

$$f(\lambda/n_i,t_i) = [\lambda(\omega+t_i)]^{n_i+\rho}\ e^{-\lambda(\omega+t_i)}/\lambda(n_i+\rho-1)!$$

which, when evaluated at $\rho = \omega = 0$, is

$$f(\lambda/n_i,t_i) = (\lambda t_i)^{n_i-1}\ e^{-\lambda t_i}/(n_i-1)!$$

Thus when the data n_i, t_i are incorporated the distribution of the spill rate λ is again a Gamma. This process obviously may be repeated with the same result as new data $(n_i, t_i;\ i = 1,2,\ldots)$ become available.

At this point in the development one has an estimate not simply of λ, but of its entire posterior probability density distribution. The authors proceed to derive from it a prediction or distribution of the probability of observing a given number of spills in a given future exposure. But if only an estimate of the spill rate λ is required, the above distribution $f(\lambda/n_i t_i)$ is completely adequate. From it any number of estimates of λ may be derived, (e.g., the mean, the mode, the median). The simplest, perhaps, is the mean $\bar{\lambda}$ which is just the ratio of spills observed to exposure observed. For the ith year this is

$$\bar{\lambda}_i = n_i/t_i,$$

while for all years together it is $\bar{\lambda}$

$$\bar{\lambda} = \left(\sum_i n_i\right)/\left(\sum_i t_i\right).$$

This is the same result as obtained from the maximum likelihood estimate (1) above.

3) Least-Squares Fit

If cumulative spills are regressed against cumulative oil movement the slope of the resulting line is an approximation to the spill rate of the underlying Poisson process. As the amount of data increases the slope approaches the spill rate λ.

In fitting a straight line to the cumulative data, the origin may be considered a valid data point, i.e., the cumulative spills and cumulative oil flow may be taken as zero before any data are accumulated. This point is valid for the same reason that the cumulative data for intermediate days in the year, if they were available, would be acceptable points.

Because it is generally accepted and easy to apply, the slope of the linear regression to the cumulative data is commonly employed as an estimate of the spill rate.

Discussion

It is instructive to compare the posterior estimator with the least square fit. The two are illustrated in Figure E-1, using fictitious data points for emphasis. It is seen that:

(a) The posterior estimate $\overline{\lambda}$ is the slope of the straight line joining the origin with the last (cumulative) point. The least square straight line, on the other hand, need not pass through either the origin or the last point.

(b) The least square fit depends upon the order in which the (n_i, t_i) data are taken, while $\overline{\lambda}$ is independent of the order. This is a consequence of the next observation,

(c) The posterior estimator assumes a Poisson spill process relative to the exposure variable; the least square fit requires no assumption about the spill process.

(d) As the amount of data increases, the least square fit approaches the prior/posterior estimator.

Because of (4), least-square fit does not differ greatly from the posterior estimator in practical situations in which there are a large number of data points. For example, the two estimates were found to agree to within 1/2% for 80 data points representing the U. S. oil spill rate (spills over 50,000 gallons) from 1974-77 . Since the posterior estimator is simpler to calculate than the least square fit, and because it is the same as the maximum likelihood estimate, it is employed exclusively in the body of this report.

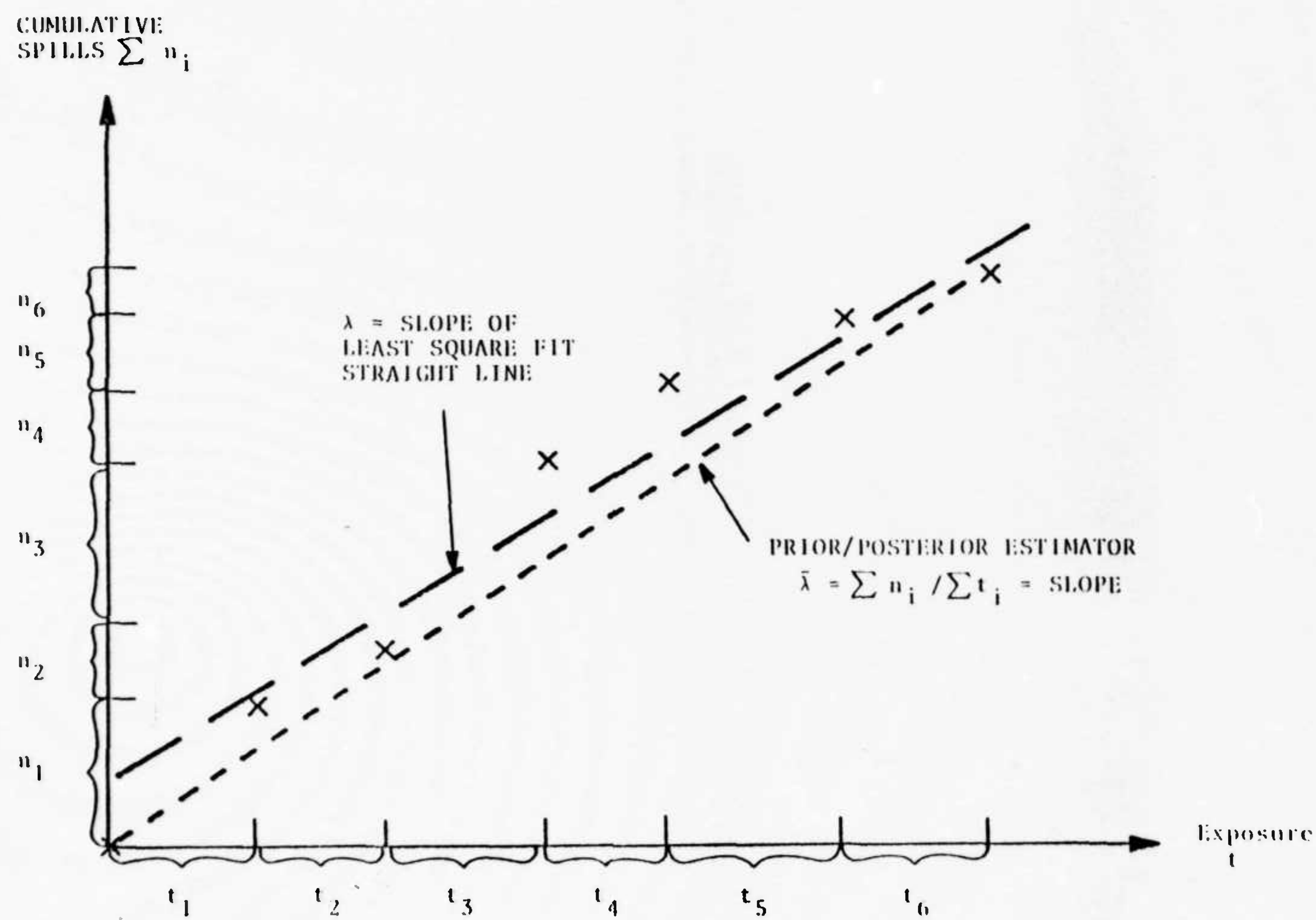

FIGURE E-1. ILLUSTRATION OF TWO SPILL RATE ESTIMATION TECHNIQUES

APPENDIX F
SIGNIFICANCE TESTING FOR POISSON PROCESSES

If spills occur according to a Poisson law then it is of considerable interest to determine whether the spill rate indicated by one set of data is significantly different from the spill rate indicated by another set of data. Methods to do so are discussed in Reference 22, Chapter 9. The following analysis is a simplified discussion of the relevant portions of that reference.

Assume n_1 events are observed from a Poisson process with exposure t_1, and n_2 events are observed from another Poisson process having exposure t_2. It is desired to determine if the number of events observed in the second process is significantly different from the number in the first process. Let the null hypothesis be that both processes have the same rate λ. It is then necessary to calculate the probability of observing n_2 events in exposure t_2 given that a total of $n_1 + n_2$ events are observed in exposure $t_1 + t_2$. As shown in Reference 22, this reduces to the calculation of the binomial probability that, in $n_1 + n_2$ trials, exactly n_2 will fall into the exposure interval t_2, when the probability for each trail is Θ:

$$P(n_2/n_1+n_2) = \binom{n_1+n_2}{n_2} \theta^{n_2} (1-\theta)^{n_1}, \qquad \text{(F-1)}$$

where

$$\theta = t_2/(t_2+t_1). \qquad \text{(F-2)}$$

In other words, if both processes have the same occurrence rate, the ratio (2) gives the probability that any one of the events falls into the exposure interval t_2. Therefore (1) gives the probability that exactly n_2 events fall into the interval t_2.

The above formulation has the advantage that it does not require a hypothesis regarding the process rate λ, but only the hypothesis that it is the same for both intervals. Thus by giving the exposure intervals t_1 and t_2, and the observations n_1 and n_2,

one can obtain the probability of the observed number of events n_2. By taking the sum

$$P\,(X>n_2/n_1+n_2) = \sum_{x=n_2}^{x=\infty} \binom{n_1+x}{x} \theta^x\,(1-\theta)^{n_1} ,$$

one may be able to determine whether the observation n_2 is inconsistent with the hypothesis of equal process rates.

If $n\ (=n_1 + n_2)$ is greater than, say, 30 the binomial function (1) cannot be readily computed, being the sum of numerous small terms. In that case, however, the binomial may be approximated by the normal distribution, (Ref.18). The number n_2, of events expected in exposure t_2 is normally distributed about the mean

$$n\theta$$

with variance

$$n\theta(1 - \theta),$$

where $n = n_1 + n_2$ and $\theta = \rho/(1 + \rho)$, with ρ equal to the ratio $\lambda_2 t_2/\lambda_1 t_1$. If it is hypothesized that $\lambda_2 = \lambda_1 = \lambda_0$, i.e., that both processes have the same rate, then

$$\theta = t_2/(t_1 + t_2),$$

and the distribution of n_2, given $n_1 + n_2$ events in toto, can be calculated without any specific assumption on λ_0.

APPENDIX G
OIL SPILL RATES IN SELECTED WESTERN RIVERS

1. INTRODUCTION

This appendix develops oil spill rates for the major Western Rivers. It serves for comparison with the spill rates in four Coastal areas (New York, Delaware Bay, Louisiana Coast, N. Texas Coast) that were investigated in the final report to which this appendix is attached.

The method followed in this appendix is similar to that employed in the main part of the report: first, the study area is defined, then the data base of spills is described, followed by the oil movement data, and concluding with the calculation and discussion of the spill rates that result.

2. STUDY AREA

The rivers covered in this appendix are those Western Rivers that carry 500,000 tons or more of oil and oil products annually. They are:

a. Lower Mississippi, from mouth of Ohio River up to and not including Baton Rouge LA.

b. Upper Mississippi, Minneapolis MN to mouth of Ohio River,

c. Illinois River, from Lockport IL to mouth.

d. Ohio River System as follows

- Ohio River, from Pittsburgh PA to mouth of river.
- Cumberland River, mouth to mile 552.
- Tennessee River, mouth to Knoxville TN.
- Allegheny River, Pittsburgh PA to above East Brady PA.

- Monongahela River, Pittsburgh PA to Fairmont WV.
- Kanawha River, mouth to mile 90.57 (head of navigation).

3. SPILL DATA

The spill data were obtained from the Pollution Incident Reporting System (PIRS), from the National Response Center (NRC) files and from the Commercial Vessel Casualty File, (CVCF), all of the U.S. Coast Guard. All spills of oil or oil products of 10,000 gallons or more from January 1974 through December 1977 contained in those records were extracted and tabulated (see Table A-1.), if they occurred in or near any of the rivers in the study region. A spill was judged to be "near" a river if it occurred within 2 miles of the river or in a city or town contiguous to the river. In practice, only one of the 36 spills (NRC #109-77) occurred near but not in one of the rivers.

In addition to the 36 recorded spills listed as within the bounds of the study, there were found to be four others that would be included except for an uncertainty in the amount spilled, and twenty others that would be included except for some uncertainty in their exact location. These are listed in Table A-2.

The four spills with uncertain quantity of oil spilled originated in the CVCF computer listing, having there a pollution indicator of 1 (light pollution). For the reasons outlined in the accompanying memorandum, these were considered as possible rather than confirmed spills. One CVCF spill was considered a confirmed spill, and included in the total, because it bore a pollution indicator of 2 (medium pollution).

The twenty spills with uncertain location originated in the PIRS listings, having there only the state as an indication of location. All of these spills are recorded as inland in a non-navigable tributary to navigable water or in an inland river, canal, or other restricted navigable waterway. All twenty were recorded in 1974 or 1975.

An analysis of Table A-1 yields a breakdown by River System and spill type (i.e., source code), shown in Table A-3. The source code classification employed in Table A-3 is as follows:

TABLE A-1. LIST OF SPILLS IN SELECTED WESTERN RIVERS, 1974-1977 (10,000 GALLONS OR MORE OF OIL OR OIL PRODUCTS)

COL 1 TWO DIGITS EACH FOR YEAR, MONTH, DAY, HOUR FOLLOWED BY ONE DIGIT TO INDICATE MULTIPLE SIMULTANEOUS SPILLS AND ONE DIGIT TO INDICATE CARD NUMBER 1 OR 2.
COL 2 LATITUDE AND LONGITUDE OR RIVER AND MILE, AS PER PIRS CODING MANUAL, CG-450, FEB 1976.
COL 3 WATER BODY NAME, WHEN AVAILABLE.
COL 4 NEAREST CITY, TOWN OR GEOGRAPHIC FEATURE.
COL 5-7 CASE NUMBERS.

COL 1 DATE/TIME	2 LOCATION	3 WATER BODY	4 CITY/STATE		5 PIRS	6 NRC	7 VCF
WESTERN RIVERS - 1							
7403032301	R LM 06695	MISSISSIPPI RIVER	TUNICA	MS	0800112		
7407190011	R LM 03633	MISSISSIPPI RIVER	NATCHEZ	LA	0801836		
7503030101	R LM 06395	MISSISSIPPI RIVER	HELENA	AR	0200137		
7503051911	R LM 04358	MISSISSIPPI RIVER	VICKSBURG	MS	0202707	320-75	60496
7511120011	R LM 07380	MISSISSIPPI RIVER	MEMPHIS	TN			60864
7511130021	R LM 05310	MISSISSIPPI RIVER	GREENVILL	MS			63662
7612270011	R LM 07200	MISSISSIPPI RIVER	MEMPHIS	TN			72469
7701042301	R LM 09520	MISSISSIPPI RIVER		KY	0200020		
7703300011	R LM 07850	MISSISSIPPI RIVER	MEMPHIS	TN			72467
7706190011	R LM 07550	MISSISSIPPI RIVER	MEMPHIS	TN			73596
7501291001	R UM 01761	MISSISSIPPI RIVER	SAINT LOUIS	MO		287-75	
7507120801	R UM 02000	MISSISSIPPI RIVER	ALTON	IL	0200590		
7511300301	R UM 01940	MISSISSIPPI RIVER	ALTON		1170	521-75	
7603121001	R UM 01800	MISSISSIPPI RIVER	SAINT LOUIS	IL	0200215	83-76	
7701101201	R UM 00423	MISSISSIPPI RIVER	CAPEGIRADEAU	MO	0200014	17-77	
7702122201	R UM 00505	MISSISSIPPI RIVER	CAPEGIRADEAU	MO		44-77	
7704021001	R UM 01758	MISSISSIPPI RIVER	SAINT LOUIS	MO	02000309	76-77	
7705072301	R UM 00166	MISSISSIPPI RIVER	CAIRO	IL		94-77	
7407030021	R IL 02750	ILLINOIS WATERWAY	JOLIET	IL			53063
7408041401	R IL 01390	ILLINOIS RIVER	BANNER	IL	0200532	2-75	
7505100101	R IL 00710	ILLINOIS RIVER	MEREDOSIA	IL	0200399	380-75	

7602082201	R	IL	01873	ILLINOIS RIVER	LACON	IL		36-76
7404252101	R	OH	09389	OHIO RIVER	CAIRO(CUMBER)	IL	0200230	
7405231501	R	OH	04696	OHIO/LICKING RIVR	CINCINNATI	OH	0200310	
7412121601	R	OH	01729	OHIO RIVER	MARIETTA	OH		239-75
7502050401	R	OH	04910	OHIO RIVER	CINCINNATI	OH	0200070	
7502101301	R	OH	00195	OHIO RIVER	ALIQUIPPA	PA	0200078	
7503011401	R	OH	00108	OHIO RIVER	PITTSBURGH	PA	0200133	
7503080901	R	MH	00005	MONONGEHELA RIVER	PITTSBURGH	PA	0200136	324-75
7510071721	R	OH	08096	OHIO RIVER	EVANSVILLEIN	KY	0200963	486-75
7512041001	R	OH	00220	OHIO RIVER	CONWAY	PA	0201243	523-75
7604081101	R	CB	01943	SIMS CREEK	NASHVILLE	TN	0200370	102-76
7604090801	R	MH	00050	MONONGAHELA RIVER	PITTSBURGH	PA	0200428	105-76
7608090701	R	AL	00720	ALLEGHENY RIVER	EAST BRADY	PA		170-76
7701130201	R	OH	04868	OHIO RIVER	CINCINNATI	OH	0200016	
7703050401	R	OH	06040	OHIO RIVER	LOUISVILLE	KY		57-77
7704050601	R	OH	06042	OHIO RIVER	LOUISVILLE	KY	0200259	77-77
7706052001	R	OH	09400	HARMON CREEK	WEIRTON	WV		109-77
7712071201	R	OH	04526	OHIO RIVER	RIPLEY	OH	0201385	
7712091501	R	OH	01747	OHIO RIVER	MARIETTA	OH	0201551	

TABLE A-1. (CONTINUED)

COL 9 SOURCE TYPE CODE, AS PER PIRS CODING MANUAL CG-450.
COL 10 NAME OF SOURCE, WHEN AVAILABLE.
COL 11 IDENTIFICATION NUMBER OF SOURCE. THIS IS USUALLY VESSEL NUMBER. CALL SIGN OR OTHER NUMBER RECORDED IN PIRS FILE.
COL 12 CAUSE/FACTOR CODE LETTERS AND DESCRIPTION, ASSIGNED ACCORDING TO PIRS CODING MANUAL, CG-450.
COL 13 PIRS CODE FOR OIL TYPE.
COL 14 QUANTITY OF OIL SPILLED, IN THOUSANDS OF GALLONS, FOLLOWED BY LETTER INDICATING SOURCE OF ESTIMATE9 P=PIRS, N=NRC, V=VCF. THE LETTERS LV, MV, HV INDICATE LIGHT, MEDIUM, AND HEAVY POLLUTION INDICATORS IN THE VCF COMPUTER FILE.

COL 8 DATE/TIME	9 SOURCE	TYPE	10 NAME	11 ID	12 CAUSE/FACTOR			13 OIL	14 QTY	
WESTERN RIVERS - 2										
7403032302	034 TNK	BARG		ON518273	AB	HLLRPT	GROUNDG	1011	21P	
7407190012	401 ONS	PPLN		00007946	CA	PPLRPT	COLLISN	1000	13P	
7503030102	034 TNK	BARG		ON510940	AA	HLLRPT	COLLISN	1011	840P	
7503051912	034 TNK	BARG	3TB+1TG	ON287014	AA	HLLRPT	COLLISN	1000	1027P	160N
7511120012	052 TUG	BOAT	MVWHITGLD	ON256109	AQ	HLLRPT	EXP-FIR		LV	
7511130022	034 TNK	BARG	T-B B924	ON550414	AQ	HLLRPT	EXP-FIR		NV	
7612270012	052 TUG	BOAT	MVSTFOSTER	ON255920	AB	HLLRPT	GROUNDG			
7701042302	034 TNK	BARG		ON511359	AB	HLLRPT	GROUNDG	1022	21P	
7703300012	03 TNK	BARG	TBCHUBBY	ON513601	AA	HLLRPT	COLLISN		LV	
7706190012	052 TUG	BOAT	MV DEL RIO	ON264305	ZB	FIRE	GROUNDG		LV	
7501291002	03 TNK	BARG	T-B JDS303		AQ	HLLRPT	UNKNOWN	1010	18N	18N
7507120802	034 TNK	BARG		ON262757	AA	HLLRPT	COLLISN	1011	10P	
7511300302	035 TNK	BARG	T-B B242	ON290662	BB	TNKRPT	GROUNDG	1040	28P	23N
7603121002	034 TNK	BARG	T-BMTVERNN	ON299026	BA	TNKRPT	COLLISN	1011	10P	10P
7701101202	035 TNK	BARG	TB T-250SL	ON270758	AB	HLLRPT	GROUNDG	1052	40P	50N
7702122202	03 TNK	BARG	T/BT-150SL		BB	TNKRPT	GROUNDG	1052	38N	38N
7704021002	101 ONS	CGTR	STORAGTANK	98588329	ND	PMPFLR	MAT-FLT	1040	17P	17N
7705072302	03 TNK	BARG	T/B LBT50		BC	TNKRPT	CORROSN	1001	30N	30N
7407030022	03 TNK	BARG	TBKENTUCKY	ON262829	AB	HLLRPT	GROUNDG		NV	
7408041402	034 TNK	BARG		ON515189	AA	HLLRPT	COLLISN	1040	88P	92N
7505100102	401 ONS	PPLN	(PIPELINE)	00088329	WK	OTHER	UNKNOWN	1000	217P	

7602082202	034	TNK	BARG	TB FLORIDA		AB	HLLRPT	GROUNDG	1020	225N	225N
7404252102	052	TOW	BOAT		ON537344	AA	HLLRPT	COLLISN	1040	13P	
7405231502	033	TNK	BARG		CG000083	AA	HLLRPT	COLLISN	1021	74P	
7412121602	502	ONS	STFY			BQ	TNKRPT	UNKNOWN	1040	35N	35N
7502050402	034	TNK	BARG		ON261395	AQ	HLLRPT	UNKNOWN	1040	82P	
7502101302	503	ONS	PRFY		55400033	WE	OVRFLO	ERROR	1000	45P	
7503011402	502	ONS	STFY		00088329	SK	TNKOFO	UNKNOWN	1010	12P	
7503080902	052	TUG	BOAT	ONWARD	ON241256	RB	EQPFLR	XSVWEAR	1095	10P	14N
7510071722	034	TNK	BARG	BARGE2181	ON504963	AB	HLLRPT	GROUNDG	1040	84P	107N
7512041002	301	RWY	CGTR	STORAGETNK	00068740	CQ	PPLRPT	UNKNOWN	1040	100P	100N
7604081102	508	NTR	PPLN	STORAGTANK	00000042	IP	PIPRPT	UNKNOWN	1040	38P	43N
7604090802	302	RWY	FLFY	STORAGTANK	00018740	TG	IMPOPN	VLV-OPN	1041	150P	150N
7608090702	201	RWY	LQBK	R-RTNKCARS	00000040	QF	RRDACD	UNKNOWN	1001	180N	180N
7701130202	401	ONS	PPLN		89540729	CJ	PIPRPT	MAT-FLT	1011	13P	
7703050402	03	TNK	BARG	TBEXNEB218		BA	TNKRPT	COLLISN	1095	13N	13N
7704050602	034	TNK	BARG	T/BHINES36000043544		AB	HLLRPT	GROUNDG	1011	75P	75N
7706052002	503	ONS	PRFY	HOLDNGPOND	00000033	HQ	STRFLR	UNKNOWN	1080		
7712071202	507	PWR	PLNT		00000049	IC	PIPRPT	CORROSN	1040	15P	
7712091502	033	TNK	BARG		CG000620	AF	HLLRPT	OTHER	1011	26P	

TABLE A-2. LIST OF SPILLS POSSIBLY QUALIFYING FOR TABLE A-1.

COL 1 TWO DIGITS EACH FOR YEAR, MONTH, DAY, HOUR FOLLOWED BY ONE DIGIT TO INDICATE MULTIPLE SIMULTANEOUS SPILLS AND ONE DIGIT TO INDICATE CARD NUMBER 1 OR 2.
COL 2 LATITUDE AND LONGITUDE OR RIVER AND MILE, AS PER PIRS CODING MANUAL, CG-450, FEB 1976.
COL 3 WATER BODY NAME, WHEN AVAILABLE.
COL 4 NEAREST CITY, TOWN OR GEOGRAPHIC FEATURE.
COL 5-7 CASE NUMBERS.

COL 1 DATE/TIME	2 LOCATION	3 WATER BODY	4 CITY/STATE	5 PIRS	6 NRC	7 VCF
1974-77 LOCATION OR QUANTITY UNCERTAIN						
7401141801			AR	880		
7401171801			KY	257		
7401260201			TN	232		
7402161101			MO	283		
7403280701			KY	658		
7406031501			OH	334		
7406071001			TN	675		
7406111201			AR	717		
7406211801			WV	381		
7407121001			OH	890		
7408020701			IL	755		
7411161201			AR	1110		
7412110701			AR	1109		
7501171201			AR	672		
7501241201			OH	232		
7504051201			IL	187		
7504271601			WI	592		
7505202101			TN	314		
7506211601			MN	805		
7512041601			OH	1232		

TABLE A-2. (CONTINUED)

COL 9 SOURCE TYPE CODE, AS PER PIRS CODING MANUAL CG-450.
COL 10 NAME OF SOURCE, WHEN AVAILABLE.
COL 11 IDENTIFICATION NUMBER OF SOURCE. THIS IS USUALLY VESSEL NUMBER. CALL SIGN OR OTHER NUMBER RECORDED IN PIRS FILE.
COL 12 CAUSE/FACTOR CODE LETTERS AND DESCRIPTION, ASSIGNED ACCORDING TO PIRS CODING MANUAL, CG-450.
COL 13 PIRS CODE FOR OIL TYPE.
COL 14 QUANTITY OF OIL SPILLED, IN THOUSANDS OF GALLONS, FOLLOWED BY LETTER INDICATING SOURCE OF ESTIMATE9 P=PIRS, N=NRC, V=VCF. THE LETTERS LV, MV, HV INDICATE LIGHT, MEDIUM, AND HEAVY POLLUTION INDICATORS IN THE VCF COMPUTER FILE.

COL 8 DATE/TIME	9 SOURCE TYPE			10 NAME	11 ID	12 CAUSE/FACTOR			13 OIL	14 QTY
7401141802	401	ONS	PPLN		66532729	IC	PIPRPT	CORROSN	1001	21P
7401171802	401	ONS	PPLN		33307929	YE	NATURL	OTHER	1001	12P
7401260202	502	ONS	STFY		33334630	SE	TNKOFL	OVR-FLL	1040	84P
7402161102	401	ONS	PPLN		55504929	IH	PIPRPT	PIP-CUT	1001	21P
7403280702	401	ONS	PPLN		44407929	IC	PIPRPT	CORROSN	1001	10P
7406031502	201	RRD	BKVL		00000040	BD	TNKRPT	OVRTURN	1000	20P
7406071002	401	ONS	PPLN		00000013	MJ	VLVFLR	IMP-OPN	1001	13P
7406111202	401	ONS	PPLN		00000046	YE	NATURL	OTHER	1001	15P
7406211802	401	ONS	PPLN		30000046	IC	PIPRPT	CORROSN	1000	15P
7407121002	502	ONS	STFY		77700046	XG	INTDCH	SAB-VAN	1001	14P
7408020702	401	ONS	PPLN		88804929	IC	PIPRPT	CORROSN	1001	42P
7411161202	401	ONS	PPLN		55553729	IC	PIPRPT	CORROSN	1001	15P
7412110702	504	ONS	PRFY		00070029	IG	PIPRPT	IMP-MTN	1001	19P
7501171202	401	ONS	PPLN		44400029	IH	PIPRPT	PIP-CUT	1001	23P
7501241202	401	ONS	PPLN		88800046	IC	PIPRPT	CORROSN	1010	13P
7504051202	503	ONS	PRFY		00000049	XG	INTDCH	SAB-VAN	1097	14P
7504271602	502	ONS	STFY		00000089	BG	TNKRPT	WEATHER	1095	12P
7505202102	503	ONS	PRFY		00000028	XG	INTDCH	SAB-VAN	1040	12P
7506211602	401	ONS	PPLN		99904929	IH	PIPRPT	PIP-CUT	1011	106P
7512041602	502	ONS	STFY		00000046	CQ	PIPRPT	OTHER	1022	40P

TABLE A-3. ANALYSIS OF SPILLS OF TABLE A-1
BY RIVER SYSTEM AND SOURCE

	River System				
Spill Source	Lower MR	Upper MR	Illinois	Ohio	Total
Vessel-Related	5	7	3	8	23
Marine Facility	0	1	0	0	1
Onshore	1	0	1	10	12
Year					
1974	2	0	2	3	7
1975	3	3	1	6	13
1976	0	1	1	3	5
1977	1	4	0	6	11

Vessel-Related Spills: PIRS source codes 000 through 058
Marine Facility Spills: PIRS source codes 100 through 108, and 505
Onshore Spills: All other PIRS source codes, except 506 and 402, which are offshore drilling and production spills

Table A-3 also breaks down spills by year and source type.

4. EXPOSURE DATA

The exposure variable employed is millions of tons of oil movement on the selected rivers as recorded for 1974 through 1977 by the Army Corps of Engineers (ACOE), "Waterborne Commerce of the United States." The data are given in Table A-4, which has been extracted from Part 2 of the ACOE volumes. The total movement of light, heavy and crude for the four river systems in 1974 through 1977 are:

Lower Mississippi	102,008,000 tons
Upper Mississippi	90,057,000
Illinois	25,829,000
Ohio	122,459,000.

It should be noted that these totals include through oil movement as well as landed and loaded oil. Thus, oil that passes from, say, Baton Rouge through the Lower Mississippi and Ohio Rivers, to be unloaded on the Allegheny, is counted three times: once for its passage through the Lower Mississippi, once for its passage through the Ohio, and once for its receipt on the Allegheny. This multiple counting allows for the added exposure of through passage, and also allows the necessary breakdown of oil movement by river system.

TABLE A-4. OIL MOVEMENT IN 1974-77 ON SELECTED WESTERN RIVERS, THOUSANDS OF SHORT TONS

	1974	1975	1976	1977
MISSISSIPPI RIVER - MOUTH OF OHIO TO BUT NOT INCLUDING BATON ROUGE				
CRUDE	3178	4346	4773	3688
LIGHT	11758	11259	13814	13877
HEAVY	9581	8103	8074	9557
MISSISSIPPI RIVER - MINNEAPOLIS TO MOUTH OF MISSOURI				
CRUDE	503	256	848	752
LIGHT	6572	6635	6751	10033
HEAVY	4250	4447	4436	4314
MISSISSIPPI RIVER - MOUTH OF MISSOURI TO MOUTH OF OHIO				
CRUDE	414	219	860	752
LIGHT	5028	5288	6024	5250
HEAVY	4238	4175	4129	3883
TOTAL, UPPER MISSISSIPPI RIVER - MINNEAPOLIS TO MOUTH OF OHIO				
CRUDE	917	475	1708	1504
LIGHT	11600	11923	12775	15283
HEAVY	8488	8622	8565	8197
ILLINOIS RIVER, LOCKPORT IL TO MOUTH				
CRUDE	65	42	175	140
LIGHT	3258	2824	3069	2879
HEAVY	3443	2973	2578	2383
OHIO RIVER, MOUTH TO PITTSBURGH, PA				
CRUDE	644	867	883	406
LIGHT	15780	15774	15928	15350
HEAVY	5728	5391	5257	6303
ALLEGHENY RIVER, PITTSBURGH PA TO ABOVE EAST BRADY, PA				
CRUDE	2	00	3	00
LIGHT	328	404	230	213
HEAVY	469	421	414	451
MONONGAHELA RIVER, PITTSBURGH PA TO FAIRMONT, WV				
CRUDE	2	00	00	47
LIGHT	1591	773	1742	1606
HEAVY	1110	1659	628	888
KANAWHA RIVER, MOUTH TO HEAD OF NAVIGATION)MILE 90.57*				
CRUDE	1	00	00	
LIGHT	954	1075	1104	1040
HEAVY	24	46	24	30
CUMBERLAND RIVER, MOUTH TO MILE 552				
CRUDE	00	3	00	00
LIGHT	727	967	1267	1049
HEAVY	252	271	271	440
TENNESSEE RIVER, MOUTH TO KNOXVILLE, TN				
CRUDE	1	1	3	12
LIGHT	1214	1676	2057	1911
HEAVY	861	1119	1189	1578
TOTAL, OHIO RIVER SYSTEM				
CRUDE	659	871	889	465
LIGHT	20594	20669	22328	21169
HEAVY	8444	8907	7783	9690

5. SPILL RATES

Spills per million tons are calculated in Table A-5 for vessel-related spills and other spills. One observes a high spill rate for the Illinois River System, both for vessel-related spills and for non-vessel-related spills. Also, the Ohio River System shows a high rate for non-vessel-related spills. The significance of these rates is difficult to judge without tests, because of the relatively few number of spills involved. Also, the existence of 24 additional spills, that may or may not be assignable to the various river systems, adds further to the uncertainty of the calculated spill rates.

Significance Tests

Table A-6 shows the results of significance testing on the spill data of Table A-5.

The tests of Appendix F with normal approximation were employed for vessel-related spills. They show no significant deviation of the observed number of spills from the expected number, as seen by the relatively high probabilities in the last column.

A different significance test was applied to non-vessel-related spills because of the small number of spills (13) involved in total. The test employed is described in section 5.3 of the accompanying final report in connection with Table 5.6. The results, given in the last column of Table A-6, show that only the Ohio River System has significant deviation from the expected number of spills, having an observation probability of .02.

Possible Spills

Before the deviation shown for the Ohio River System can be assessed fully, it is necessary to take account, if possible, of the 24 possibly relevant spills of Table A-2. Of these, 4 are vessel-related and 20 are not.

TABLE A-5. OIL SPILL RATES OF SELECTED WESTERN RIVERS, 1974-77

	SPILLS IN 1974-77	MILLIONS OF TONS, 1974-77	SPILLS PER MILLION TONS
VESSEL-RELATED SPILLS			
Lower Mississippi	5	102.0	.049
Upper Mississippi	7	90.1	.078
Illinois	3	23.8	.126
Ohio	8	122.5	.065
Total	23	338.4	.068
NON VESSEL-RELATED SPILLS			
Lower Mississippi	1	102.0	.010
Upper Mississippi	1	90.1	.011
Illinois	1	23.8	.042
Ohio	10	122.5	.082
Total	13	338.4	.038

TABLE A-6. SIGNIFICANCE TESTS OF SPILLS
IN SELECTED WESTERN RIVERS
1974-1977

	Observed Spills (1)	Expected Spills (2)	Expected Variance (3)	Probability of Observed Spills (4)
VESSEL-RELATED SPILLS				
Lower MR	5	6.9	4.84	.38
Upper MR	7	6.1	4.49	.67
Illinois	3	1.6	1.30	.23
Ohio	8	8.3	3.31	.90
Total	23	23.0		
NON VESSEL-RELATED SPILLS			(5)	(6)
Lower MR	1	3.9	3.9	.20
Upper MR	1	3.5	3.5	.28
Illinois	1	0.9	0.9	.99
Ohio	10	4.7	4.7	.02
Total	13	13.0	---	---

(1) Taken from Table A-3.

(2) Based on a uniform spill rate, and oil movement for each river system shown in Table A-3.

(3) Calculated by method of Appendix F.

(4) Calculated by method of Appendix F, employing the normal approximation.

(5) Expected variance based on Poisson Distribution with mean of expected spills, column 2.

(6) Probability of any observation differing from the mean by an amount equal to or greater than the observation of column 1.

For most of these 24 spills, the possible river assignment is unique; for the remainder there are either 2 or 3 rivers to which an assignment may be made. A breakdown of possible spill assignments is given in Table A-7. It can be seen that the number of non-vessel-related spills that may be added to any of the four river systems exceeds the number of such spills actually known to have occurred in the river system. To determine whether the ten spills actually known to have occurred in the Ohio system is still significantly high when the effect of unassigned spills is allowed for, one may make an assignment of non-vessel-related spills from Table A-7 according to some assumed rules. For present purposes the rules adopted are, for each river system:

1. One half of non-vessel-related spills of type 1. in Table A-7 are assigned.
2. One-fourth of non-vessel-related spills of type 2. in Table A-7 are assigned.
3. One-sixth of non-vessel-related spills of type 3. in Table A-7 are assigned.

With the above rules, the number of observed spills is increased by assigned spills, as shown in Table A-8. The result of the significance tests, performed as before on non-vessel-related spills, is also shown in that table.

It is seen that the Ohio River System still shows significantly more spills than expected, but the significance level is 95% instead of 98%. This level of significance indicates that the Ohio River area probably has more non-vessel-related spills than normal even when the likely effects of possible other spills in the area are allowed for. It is apparent then, that the 24 spills possibly assignable to the river systems should be investigated individually in order to resolve with greater certainty the apparently high rate of non vessel-related spills in the Ohio River System. If the high spill rate is confirmed then a further investigation is required to determine its causes.

TABLE A-7. POSSIBLE SPILL ASSIGNMENTS TO ONE OR MORE OF THE FOUR WESTERN RIVER SYSTEMS

Number of Spills that could have occurred	River System(1) LM	UM	IL	OH	Total
1. In one of the River Systems	9*	2	0	5	
2. In one of two River Systems	6	1	0	5	
3. In one of three River Systems	0	2	2	2	
Maximum Number of spills that could have occurred in the River System	15*	5	2	12	

*Includes four vessel-related spills. All other spills are not vessel-related.

(1) Lower Mississippi, Upper Mississippi, Illinois, Ohio.

TABLE A-8. WORST CASE ANALYSIS OF OHIO RIVER NON-VESSEL-RELATED SPILLS

	Observed plus Assigned Spills	Expected Spills	Expected Variance	Probability of Observed & Assigned
NON VESSEL-RELATED SPILLS				
Lower Mississippi	4.8	6.8	6.8	.57
Upper Mississippi	2.6	6.1	6.1	.30
Illinois	1.3	1.6	1.6	.99
Ohio	14.1	8.3	8.3	.05
	22.8	28.	---	---

6. RESULTS

The results of this study are based on a total of 36 spills over 10,000 gallons recorded in PIRS, NRC and VCF in the selected Western Rivers, from 1974 through 1977. In addition some 24 other spills are recorded that may have occurred in or near one of the selected rivers. The major results are:

a. The number of vessel-related spills per million tons of oil movement shows no significant deviation from one river system to another.
b. Vessel-related spills per million tons of oil movement in the Western Rivers are about equal to total spills per million ton of oil movement in the four coastal regions investigated in the final report.
c. Non vessel-related spills per million tons of oil moved have no significant deviations among the selected Western Rivers, except for the Ohio River System.
d. The non vessel-related spill rate in the Ohio River system appears to be about twice the rate in other parts of the Western Rivers. The significance level is 98%, but this significance level can be strongly affected by the 24 additional spills that may fall into the Western Rivers. (A trial assignment reduced the significance level to 95%). The exact location of these additional spills must be ascertained before a definite significance level can be estimated for the non-vessel-related spills in the Ohio River System.

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in the area are allowed for. It is apparent then, that the 24 spills possibly assignable to the river systems should be investigated individually in order to resolve with greater certainty the apparently high rate of non vessel-related spills in the Ohio River System. If the high spill rate is confirmed then a further investigation is required to determine its causes.

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